GENERAL ANAESTHESIA
FOR DENTAL SURGERY

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by

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WITH A FOREWORD BY

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AUTHOR'S PREFACE

THE administration of Nitrous Oxide for dental anaesthesia is essentially a practical rather than a scientific branch of the specialty, and one in which proficiency is difficult to achieve without constant practice.

The practical instruction which is available for the teaching of dental anaesthesia to medical and dental students during their undergraduate training is often limited by the small number of patients attending hospital clinics, yet dental anaesthetics are unique in being given almost exclusively and in very large numbers by non-specialists, both doctors and dentists.

This book aims at emphasising the attention to detailed and practical points which is essential for success, and which, if ignored, can lead to repeated difficulties. It is written primarily for students and general practitioners of both medicine and dentistry, and also for the trainee specialist anaesthetist whose opportunities to gain experience are again often limited The techniques described are well tried and standard, but new drugs and methods have been included where applicable.

At the present time the evils of oxygen lack are becoming more widely recognised, and the techniques of dental anaesthesia are being generally re-examined with this in view. In describing the classical methods the book emphasises the dangers of anoxia in the unfit patient and alternative techniques are suggested.

For those interested in reading further some relevant references are included at the ends of the chapters, but this is not intended to be a complete bibliography. The opening chapters include a short résumé of the physiological and pharmacological basis of the subject. Local analgesia is not included, since it is taught to the dental student by his surgical tutors and rarely comes within the province of the doctor.

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Senior Consultant Anaesthetist, St. George's Hospital

THE very important question of the mortality and morbidity resulting from the administration of anaesthetics for dental surgery is now under active consideration by a special committee set up by the Association of Anaesthetists. The related subject of the teaching of dental anaesthetics is also under review. Dr. Walsh's new book appears, therefore, at an appropriate moment.

Just as no man learns to swim by taking a correspondence course, so competence in the giving of dental gas cannot be attained by reading in a library. Nevertheless, there is much that can be usefully written on the matter and much help can be gained from its perusal, (*a*) when one is truly a beginner, (*b*) at that mid-period when one has learnt enough to realise how little one knows, and (*c*) in that dangerous period which lasts all his active life, when familiar routine tends to dull the edge of unremitting care.

In so far as the essential details of what is primarily a practical art can be conveyed in print it seems that Dr. Walsh has covered the ground. It is to be hoped that the value of his book to its reader will be commensurate with the effort and care that have gone into its production.

I am grateful to the anaesthetists of St. George's Hospital and the Royal Dental Hospital, from whom much of the technique has been learned, and I wish to express my thanks to Dr. R. P. W. Shackleton for his helpful criticism and advice in the preparation of the manuscript.

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CHAPTER ONE

Introduction and Physiology

In this country and the U.S.A. general anaesthesia has become an accepted and indispensable accompaniment to dental surgery, particularly for the extraction of teeth. From the earliest days dentists have sought a safe and convenient general anaesthetic to help them and their patients, and the early history and progress of anaesthesia owe much to the dental profession. Wells and Morton of the U.S.A. were pioneers in this respect at the middle of last century, while the first recorded ether anaesthetic in this country was for the extraction of teeth.

Nitrous oxide attracted the attention of dentists and their anaesthetists very early on, and though it temporarily lost ground to ether and to chloroform it returned to favour with the invention of suitable apparatus for administering the gas and the development of reliable supplies. With standardised equipment and easily available cylinders nitrous oxide anaesthesia has achieved a pre-eminent position which has withstood the test of time and which still has no serious rival, notwithstanding the introduction of new drugs and techniques.

The advantages of nitrous oxide lie in its relative safety, its pleasantness to inhale, and the rapidity of induction and recovery, allied with the almost complete absence of after-effects. Like all anaesthetics it is no safer than the skill of the administrator permits, and the competence of the anaesthetist remains much more important than the precise pharmacology of the drugs he uses.

Anaesthesia involves the abolition of consciousness, the obliteration of many of the protective reflexes which guard the waking patient from common physiological hazards, and his temporary intoxication to a state not far from death. It is important accordingly not to embark upon anaesthesia lightly or without clinical justification.

An anaesthetist must be able to recognise the signs of anaesthesia and to adjust from moment to moment the depth of the anaesthetic,

and most important he must take over the responsibility for the physiological well-being of the patient whose own protective reflexes he has obtunded.

A basic knowledge of the principles of physiology, particularly of the respiratory and cardiovascular systems is necessary to understand the mechanisms involved in anaesthesia and the disturbances which it may cause.

Respiration

The main muscles of respiration are the intercostals and the diaphragm, whose actions combine to make inspiration the active phase of breathing, and expiration a passive act effected by the elastic recoil of the tissues. The anatomical arrangement of the intercostals makes it difficult to evaluate the precise actions of any particular group, but they cause the thoracic cage to be raised, pivoting the ribs about the costo-vertebral joints and increasing both the antero-posterior and side-to-side diameters of the chest.

The diaphragm has a dual action. When it contracts the dome is lowered and the depth of the thorax is increased, and at the same time the lower ribs are raised and intercostal breathing is assisted.

When greater respiratory movements are required than can be given by this mechanism the accessory muscles of respiration are called into play. These include the pretracheal muscles and the sternomastoids, which help to raise the thoracic cage; the pectorales and latissimi dorsi, which help the rib movements when the arms are fixed by the subject holding on to some object; the muscles of the abdominal wall, which force up the diaphragm in expiration; and the pharyngeal muscles and those of the external nares, which widen the airway.

Control of Respiration

The respiratory movements are controlled by the respiratory centres of the brainstem, which order the phasing of the respiratory cycle and determine the depth and frequency of breathing. The normal chemical stimulus to breathe is the accumulation of carbon dioxide in the blood, and the respiratory mechanism keeps the arterial pCO_2 very constant in the healthy body at 40 mm. Hg. A rise in the pCO_2 directly stimulates the respiratory centres and increases the depth and frequency of breathing. This washes out the

excess CO_2 from the lungs and so from the blood. A fall in pH, or a rise in temperature has the same effect.

Nervous Control

The respiratory centres are influenced by numerous stimuli coming from many parts of the body. Among the more important are those arising from the pulmonary stretch receptors. Inspiratory distension of the lungs stimulates these receptors in the lung parenchyma, and they discharge nervous impulses along the vagi. These impulses inhibit the respiratory centres so that inspiration is stopped and expiration is allowed to take place.

Reflexes from the chemoreceptors

The carotid and aortic bodies, which are groups of chemoreceptor cells arranged near the bifurcations of the carotid arteries and also near the arch of the aorta, are sensitive to a reduction of blood oxygen tension (and to a lesser extent to a rise in CO_2). If the O_2 falls, the respiratory centres are reflexly stimulated via the nerve to the carotid sinus and the vagus. Any but the slightest hypoxia is a depressant to the centres themselves and makes them incapable of responding to the reflex stimuli arising in the carotid area. Severe hypoxia is thus a respiratory depressant.

The respiration is also increased by a fall in blood pressure, such as occurs in haemorrhage when the patient suffers from "air-hunger". This is a carotid sinus reflex.

Other significant reflexes arising in the respiratory tract include those involved in the complex acts of coughing and sneezing, which can be stimulated by foreign bodies in the air passages.

Many other stimuli may modify the action of the respiratory centres, including those arising in the joints, in the special sense organs and in the higher centres, which give some degree of voluntary control of the breathing.

The subjective sensations of a desire to breathe have two sources. First the responses from the stretch receptors in the lungs, and secondly the blood O_2 and CO_2 tensions. To avoid a feeling of suffocation rhythmic stimulation of these receptors by respiration is necessary, and the unpleasant sensations caused by breath holding are partly the result of the absence of such stimulation. As long as respiration is unimpeded there is no sense of suffocation despite gross alteration

of the blood gas tensions. That there is also some correlation between comfort and blood carbon dioxide is shown by the ability to hold the breath for longer than usual if the subject first overbreathes to wash out some CO_2 from his blood.

The above data has application in dental anaesthesia, since induction with nitrous oxide usually involves some hypoxia. This does not give rise to feelings of suffocation as long as there is no respiratory obstruction, although the subject becomes aware of the increased excursion of his breathing.

Respiratory exchange

At rest the average adult breathes about 16 times per minute, moving 400–500 ml air at each breath. This is called the "tidal air". About 150 ml. of the tidal air occupies the "dead space", that is the air in the mouth, trachea, and bronchi which does not take part in the gaseous exchange. The dead space is clinically important, and is responsible *inter alia* for the inefficiency of shallow breathing.

In normal breathing, using the above figures, the dead space occupies one-third of the tidal air. If the rate of respiration is doubled, and the tidal air halved, three-fifths of the tidal air is dead space, so the effective respiratory exchange is reduced from 300 to 100 ml. (at double the rate), i.e. by one-third.

It is of paramount importance to keep the dead space as small as possible in anaesthetic equipment. If a face mask adds, say, 150 ml. to the dead space, this will then total 300 ml., a large proportion of the tidal air, which will itself need to be increased by deeper respiration to keep the alveolar gases at their normal levels. This is particularly important in children whose tidal air may be so small that an apparently innocuous increase in dead space can swamp it completely. The effective dead space in open circuit anaesthetic equipment is the volume of gas passages between the nose (or face) and the expiratory valve. For this reason the expiratory valve is always placed as close as practicable to the patient. Fortunately dental nasal masks are easy to design with a small dead space, and it will be noted that the expiratory valve is invariably mounted on the mask itself

Alveolar Air

The normal composition of the gas mixture in the alveoli, known as the "alveolar air", is: O_2 14%, CO_2 5·5%, N_2 80·5%. This is

saturated with water vapour, and the partial pressures concerned are (at N.T.P.):

Water vapour	45 mm. Hg	Carbon dioxide	40 mm. Hg
Oxygen	100 mm. Hg	Nitrogen	575 mm. Hg

(The partial pressure of one component of a gas mixture in a closed container is the pressure which that gas would exert if it alone filled the container.)

The gases involved in respiration pass between the blood and the alveoli and vice versa across the alveolar membrane, which is the thin (about 1μ) barrier separating them. This has a very large potential functional area, of the order of 100 sq. metres, though not all the alveoli or capillaries are open at any one time. The alveolar membrane should be regarded more as a film of water than as a dry semipermeable membrane, and gases diffuse across it at a rate proportional to the gradient of partial pressure for that gas across the two sides of the membrane. Individual gases diffuse at different speeds for a given pressure gradient depending partly on their solubilities in water and partly on their molecular weights. Carbon dioxide, which is very soluble in water, diffuses readily across the membrane.

Pressure gradients

With the body at rest blood arrives at the alveoli with a pCO_2 of 46 mm Hg. By the time it has traversed the pulmonary capillaries it is in equilibrium with the alveolar CO_2, i.e. 40 mm. Hg, showing that a pressure gradient of 6 mm. Hg is sufficient to produce the necessary diffusion across the alveolar membrane. In contrast the pO_2 of pulmonary artery blood (at rest) is 40 mm. Hg. During its passage through the lungs there is a pressure gradient of 60 mm. Hg between the alveoli and blood, but this is insufficient to produce equilibrium, and the blood leaves with a pO_2 of only 90 mm. Hg. The partial pressure gradient of the O_2 is 10 times that of the CO_2, but this is more than compensated by the greater solubility of carbon dioxide. Nitrous oxide, with which dental anaesthetists are concerned, has a solubility comparable to carbon dioxide.

Oxygen Transport

Oxygen is carried by the blood both in direct solution in the plasma (0·3 ml./100 ml. blood) and in combination with haemoglobin. This

is a loose chemical combination, and oxyhaemoglobin is formed. The dissociation curve of oxyhaemoglobin is such that it is 97·5% saturated at the arterial pO_2 of 90 mm. Hg. Provided the patient's haemoglobin is 100% (15 grammes/100 ml. blood) the haemoglobin carries about 19 ml. of oxygen per 100 ml. blood.

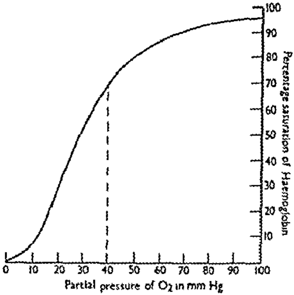

FIG 1 A graph relating percentage of haemoglobin oxygen saturation to the partial pressure of oxygen in contact with whole blood. The curve becomes steep at about 40 mm Hg.—that of venous blood. Any further reduction in tension releases large volumes of oxygen to the tissues (After Halliburton)

At rest the oxygen demands of the tissues abstract 5 ml. of oxygen per 100 ml. blood, leaving it 70% saturated with oxygen. This saturation lies on a steep part of the curve of dissociation of oxyhaemoglobin, so any further reduction of pO_2 at the tissues liberates relatively large quantities of oxygen from the blood. Dissociation of oxyhaemoglobin at the tissues is further helped by the higher pCO_2 at this site, which reduces the power of haemoglobin to retain oxygen in combination and so makes further volumes of oxygen available. This process is reversed at the lungs where the pCO_2 is lower.

The prolonged inhalation of pure oxygen washes out nitrogen from the lungs and raises the alveolar oxygen tension to nearly 700 mm. Hg.

This will increase the oxygen carried by 2 ml./100 ml. blood—a rise of 10% above normal. This is made up of 1·5 ml. extra in simple solution in the plasma, and 0·5 ml. due to a rise in saturation of haemoglobin from 97·5% to 100%. This extra oxygen represents two-fifths of the resting demands of the tissues.

Cyanosis

Cyanosis is a colour change of the blood from bright red to dusky blue, which is visible in the skin and mucous membranes. Cyanosis appears when 5 grammes of reduced haemoglobin are present in 100 ml. of blood. This is NOT a percentage reduction of the blood, but an absolute figure, and the importance of the distinction is seen if the anaemic patient is considered. With a haemoglobin of 50%—not very uncommon—and representing 7·5 grammes/100 ml, cyanosis will not appear until two-thirds of the haemoglobin is reduced. In the more extreme case with haemoglobin of 33% (5 grammes/100 ml.) there will be no cyanosis until all is reduced, a state incompatible with life. Hence if cyanosis is relied on in these cases as a guide to oxygenation, the anaesthetist can be seriously misled.

Under certain circumstances a locally poor circulation can cause stagnation of venous blood in the skin and the appearance of peripheral cyanosis, despite full oxygenation of arterial blood, but in outpatient anaesthesia it can be taken for practical purposes that the colour of the blood in the skin reflects that of the arterial blood.

Nitrous Oxide

One reason for the use of inhalation as a route for administering anaesthetics is the ease with which the blood anaesthetic concentration can be controlled. Increasing the inhaled concentration of the drug concerned will deepen anaesthesia, while removal of the mask at once allows elimination to start through the lungs. This is in contrast to the intravenous route where the injection to induce or to deepen anaesthesia is simple and rapid, but its withdrawal must wait upon the excretion or metabolic degradation of the drug. Recovery is therefore usually slower, and accidental overdosage harder to treat than when inhalation anaesthetics have been used.

The speed of induction of anaesthesia with nitrous oxide depends on the rate at which it is brought to the alveoli, and the speed at which

it diffuses into the blood and is carried to the brain. As the gas is non-irritant it can be inhaled in high concentrations, up to 100%, and at once arrives at the alveoli. Irritant drugs such as ether cause breath holding and limit the concentration in which they can be given, and this slows induction.

Nitrous oxide is very soluble in water and in blood, so it diffuses across the alveolar membrane and dissolves in the blood with great ease, and the rate of induction is only limited by the cardiac output. In short anaesthetics it is not necessary to equilibrate all the blood or all the body tissues to the inhaled concentrations of the gas. A large part of the cardiac output is directed to the brain, where the anaesthetic is required to act, and the brain anaesthetic levels follow those of the blood much more quickly than does the rest of the body. To produce 90% equilibrium of the whole body to nitrous oxide requires about 30 minutes anaesthesia.

The presence of nitrous oxide in the blood has no influence on the carriage of oxygen, but owing to the low potency of the gas it has to be inhaled almost pure in outpatient anaesthetics, which means the exclusion of oxygen from the lungs and incidental hypoxia from this.

It is useless to endeavour to increase the potency of the gas by giving it under pressure, as is sometimes done. The normal atmospheric pressure is 760 mm. Hg, and that in the lungs is identical to this within a few mm. Hg even at the extremes of respiration If nitrous oxide is given at a positive pressure of 20 mm. Hg, and more than this is unlikely to be tolerated, the increase in pN_2O of the blood cannot be more than $\frac{20}{760} \times 100\%$, i.e. 2·6%, and even this is unlikely to be attained in practice. It is improbable that an increase of this order would be detectable clinically, and the benefits which sometimes accrue from giving the gas under pressure are the result of the obliteration of inward air leaks and mouthbreathing of air by the pressure of the gas in the nasal passages.

Actions of Nitrous Oxide

The precise mode of action of this, as of any anaesthetic, is imperfectly understood, although many theories have been suggested. It is soluble in the fat tissues which abound in the central nervous system, and there is evidence to suggest that it acts at the cell mem-

brane, or on the mitochondria, possibly by interfering with some phase of intracellular oxidation. This is a reversible and non-toxic action.

Effects of Hypoxia

Hypoxia is most accurately classified by considering its aetiology, e.g. histotoxic, anaemic, etc., but in outpatient anaesthesia we are almost exclusively concerned with anoxic hypoxia—a reduction in both the partial pressure and the content of oxygen in the arterial blood. This is usually the result of breathing nitrous oxide in concentrations which exclude oxygen from the lungs and blood.

Hypoxia is always undesirable, but in outpatient work short periods of moderate hypoxia are tolerated reasonably well in the fit patient, and some hypoxia is incidental to almost every dental "gas". The physiological effects which it causes are important, and are discussed in Chapter 8. Briefly they are an initial stimulation, followed by depression of the central nervous system—which can only too easily be permanently damaged—and a secretion of adrenalin. This causes a rise in pulse rate, in blood pressure, and in cardiac output, as well as a rise in blood sugar. Further hypoxia depresses the cardiovascular system, and causes the heart to stop. **Unwise hypoxia is the commonest cause of death under anaesthesia.**

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CHAPTER TWO

Pharmacology

THE dental anaesthetist is concerned almost exclusively with nitrous oxide, but he has occasion to use other drugs to supplement this, and a knowledge of their main pharmacological actions is necessary to be able to employ them safely and to their best effect. The details of all their actions are not included, but only those applicable to dental work.

Nitrous Oxide

This is a gas at N.T.P., but it liquefies under about 30 atmospheres pressure at room temperature, and it is in this form, compressed in steel cylinders, that it is dispensed To conform with international standards they are coloured blue. The gas is stable in storage, and will neither burn nor explode, though it will support combustion, since it is exothermically decomposed by moderate heat into oxygen and nitrogen.

It is not altered in the body and is excreted entirely through the lungs. Apart from producing unconsciousness and anaesthesia it is remarkable in having practically no pharmacological actions on any organ, and being nearly non-toxic. It is a weak anaesthetic, and without supplementary drugs has to be inhaled in concentrations of 50–80% to cause unconsciousness, and 85–90% to give anaesthesia as deep as the first plane of the third stage, depending on the length of time for which it is inhaled.

In practice some degree of hypoxia has to be accepted, but it is most important to be clear that it is a true anaesthetic in its own right and does not rely on hypoxia for its effects. While trick anaesthetic demonstrations can be given using nitrogen alone for the "anaesthetic", and relying on the hypoxia to produce unconsciousness and insensibility to pain, the results are very different from those given by N_2O. Any doubts about the anaesthetic potency of nitrous oxide can be dispelled by the student inhaling a mixture of 80% N_2O,

and 20% O_2 for five or six breaths. This contains as much oxygen as the air, yet will produce analgesia and disorientation, and a state not far from anaesthesia, without hypoxia. A warning is necessary against any such experimenting without another capable person being present. Fatal accidents are recorded from time to time due to disregard of this precaution and, in addition, addiction to nitrous oxide is not unknown amongst anaesthetists and dentists to whom it is readily available. Do not make a practice of inhaling the gas unnecessarily.

In lower concentrations the gas produces analgesia, defined as a loss of pain sensation without unconsciousness. Apart from this there is no notable action on the central nervous system. The medullary centres are not affected and vomiting is rare.

The gas has no action on the cardiovascular system, and the cardiac output, the pulse rate and the blood pressure are unaltered.

The respiratory system is unaffected. The salivary and bronchial secretion are not stimulated and the bronchial musculature is unaffected.

There are no changes in blood chemistry, but marrow failure and aplastic anaemia has been reported after several days' continuous administration in the treatment of tetanus. The gas is non-toxic to liver or kidneys, and it does not give muscle relaxation.

Outpatient administration usually incurs some hypoxia, and the changes this produces are detailed in Chapters 1 and 8.

Trichloroethylene

This is marketed in this country as the branded product "Trilene", which is coloured blue and has thymol added as a preservative. Its smell is distinctive and not too unpleasant. Its volatility is too low for an open mask to be used and a vaporiser is necessary. Its effective concentrations for supplementing nitrous oxide lie between 0·2–2%. Induction and recovery are swift, the greater part being excreted via the lungs, though some is detoxicated in the liver and excreted in the urine. It is non-explosive in air or oxygen, but it may not be used in a circuit with sodalime since this decomposes it into toxic substances.

In sub-anaesthetic concentrations it has useful analgesic properties.

Blood pressure, pulse, and cardiac output are little altered, but

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pressure in glass tubes. It burns in air and is explosive. It is usually dispensed with Eau de Cologne to disguise the smell, which in anaesthetic concentrations is pungent. In dental surgery it can be given by spraying on the open mask or on the pack.

The medullary centres are not affected until deep anaesthesia, but the drug is very toxic to the heart. Respiration is initially stimulated, and this adds to the cardiac dangers. There is little salivation.

Liver function is reduced more than by trichloroethylene, so the drug should only be used for short procedures. Muscle relaxation is poor.

This drug is widely used, but is none the less dangerous and primary cardiac failure is an ever-present risk. A much safer drug is:

Vinyl Ether

A clear colourless volatile liquid with an unpleasant garlic-like smell, which is explosive in air and oxygen over wide ranges of concentrations. Boiling point 20°C. It is supplied commercially as "Vinesthene", which contains alcohol to prevent freezing of water vapour on an open mask, and phenyl-α-naphthylamine as a preservative. The drug decomposes relatively fast and opened ampoules should be used within 48 hours. In dental anaesthesia it is given on the open mask, in a closed inhaler such as the "Oxford", or is added to the gases from the machine by a drip feed such as "Goldman's".

It is effective in air in concentrations of about 4%, but lower if added to nitrous oxide. The vasomotor and respiratory centres are unaffected and vomiting is rare. It is not a cardiac depressant and the pulse rate, blood pressure, and cardiac output remain unaltered.

Respiratory exchange is increased in light anaesthesia. Secretions are markedly stimulated and salivation is profuse.

This drug is toxic to the liver if administered for more than about half an hour, or if inhaled for repeated anaesthetics, but no ill-effects follow short administrations. Muscle relaxation is poor.

The drug can be used in all situations where ethyl chloride might be given, with no disadvantages and much greater safety.

Cyclopropane

This is not often used in dental anaesthesia but has certain special applications where it is of value. It is a gas at N.T.P. and is stored at

overdosage causes extra-systoles and an irregular pulse, with rapid shallow breathing. It must not be used with adrenaline, since these two together may cause ventricular fibrillation and cardiac arrest. The blood chemistry is not affected, but sensitive tests of liver function such as the thymol turbidity indicate a slight and transient disturbance of function, which returns to normal within 24 hours.

The drug will not give muscle relaxation.

Halothane

Halothane is the official name for a recently developed fluorinated hydrocarbon, and is marketed exclusively at present under the trade name Fluothane. It is a clear colourless liquid with a pleasant smell resembling apples, and is not inflammable in any mixture with oxygen. It is usually administered in a similar way to trichloroethylene described above, but its volatility is sufficient for it to be effective on the open mask. 0·5% is sufficient to supplement nitrous oxide, but 2% in air is required to produce anaesthesia.

Analgesia is not a marked feature with subanaesthetic concentrations, but nausea and vomiting are rare. Recovery and induction are rapid. Both the vasomotor and the respiratory centres are depressed, and shallow and sometimes rapid breathing with a fall in blood pressure are common. The pulse rate is slowed, and if more than the smallest concentrations are used the previous administration of atropine is essential.

It produces the sensitisation of the heart to adrenaline seen with all halogenated hydrocarbons and these drugs cannot be used in combination. The fall in blood pressure is marked if competitive blocking muscle relaxants are used (particularly *d*-tubocurarine). The bronchial muscles are relaxed, and the drug is specially suitable for use in bronchospastic states such as asthma

The changes in body chemistry are slight, and comparable to those following trichloroethylene. Muscle relaxation is particularly good, and dental operating conditions are very satisfactory. The drug's potency is comparable to that of chloroform, though it appears to be without the latter's disadvantages.

Ethyl Chloride

This is a volatile liquid whose boiling point is 12·5°C., i e. below normal room temperature, so it is kept as a liquid under slight

pressure in glass tubes. It burns in air and is explosive. It is usually dispensed with Eau de Cologne to disguise the smell, which in anaesthetic concentrations is pungent. In dental surgery it can be given by spraying on the open mask or on the pack.

The medullary centres are not affected until deep anaesthesia, but the drug is very toxic to the heart. Respiration is initially stimulated, and this adds to the cardiac dangers. There is little salivation.

Liver function is reduced more than by trichloroethylene, so the drug should only be used for short procedures. Muscle relaxation is poor.

This drug is widely used, but is none the less dangerous and primary cardiac failure is an ever-present risk. A much safer drug is:

Vinyl Ether

A clear colourless volatile liquid with an unpleasant garlic-like smell, which is explosive in air and oxygen over wide ranges of concentrations. Boiling point 20°C. It is supplied commercially as "Vinesthene", which contains alcohol to prevent freezing of water vapour on an open mask, and phenyl-α-naphthylamine as a preservative. The drug decomposes relatively fast and opened ampoules should be used within 48 hours. In dental anaesthesia it is given on the open mask, in a closed inhaler such as the "Oxford", or is added to the gases from the machine by a drip feed such as "Goldman's".

It is effective in air in concentrations of about 4%, but lower if added to nitrous oxide. The vasomotor and respiratory centres are unaffected and vomiting is rare. It is not a cardiac depressant and the pulse rate, blood pressure, and cardiac output remain unaltered.

Respiratory exchange is increased in light anaesthesia. Secretions are markedly stimulated and salivation is profuse.

This drug is toxic to the liver if administered for more than about half an hour, or if inhaled for repeated anaesthetics, but no ill-effects follow short administrations. Muscle relaxation is poor.

The drug can be used in all situations where ethyl chloride might be given, with no disadvantages and much greater safety.

Cyclopropane

This is not often used in dental anaesthesia but has certain special applications where it is of value. It is a gas at N.T.P. and is stored at

about 75 lb. per sq. inch at room temperature. It is relatively expensive and therefore has to be given for reasons of economy in a closed system involving rebreathing. It is explosive over exceptionally wide ranges of concentrations.

The drug has no toxic actions and hepatic and renal function are unimpaired. Muscle relaxation is adequate.

INTRAVENOUS AGENTS

Thiopentone

This is marketed under a variety of trade names, of which "Pentothal" has become almost a household word with the general public. It is a thiobarbiturate designed for intravenous administration, though it can also be given per rectum. Its intravenous action is rapid, limited only by the circulation time, so it is used in dental surgery as an induction agent preceding general anaesthesia both for those who have a morbid fear of "gas" and as a convenient supplementary agent to give smooth anaesthesia in the resistant cases (see Chapter 7). The drug is dispensed dry in ampoules in an atmosphere of nitrogen, since it slowly decomposes in solution. It is supplied commercially in ½ or 1 gramme doses with a suitable amount of sterile water to make 2½% or 5% solutions. The powder should dissolve almost at once to give a clear yellow-green fluid, which is alkaline and has a pH about 10. This is an irritant solution, and accidental intra-arterial injection must be avoided, for it causes intense arterial spasm and gangrene.

The apparently evanescent action of all the ultrashort-acting barbiturates is not due to detoxication, but to their initial direction during induction to the brain, because of the latter's relatively good blood supply. This gives a rapid onset of anaesthesia. Recovery and awakening result from redistribution of the drug from the brain to all the tissues of the body, particularly the fat, whose blood supply is relatively poor. When equilibrium is reached (and the time taken for this depends on the relative circulations of the brain and the fat tissues) the blood thiopentone level (and hence that of the brain) is below that needed for anaesthesia, and the patient awakes. Detoxication, which takes place mainly in the liver, is on the other hand a slow process, taking about 4 hours for the average anaesthetic dose. Two important

conclusions arise from this. Firstly, a very large dose will result in the blood level being high enough to cause anaesthesia even after redistribution has occurred, and unconsciousness will be prolonged. Secondly, the patient will not have completely recovered and detoxicated even a small dose for some hours after he has regained consciousness, and some "hangover" effect is indeed found. Thiopentone and other short acting barbiturates are not recoverable from the urine.

It is a hypnotic with rapid action, and except in large doses has little analgesic action. Thiopentone is a potent anti-convulsant, and it will control the convulsions caused by overdosage of local anaesthetics. For this only small sub-anaesthetic doses of 50–100 milligrams are needed. It causes marked medullary depression. Respiration becomes very shallow or may cease after a small dose and the blood pressure falls. Vomiting is uncommon.

It is a direct cardiac depressant, particularly in the old and unfit in whom it is dangerous for this reason. The erect posture needs special care because it accentuates the fall in blood pressure. The pulse rate rises initially from the fall in blood pressure, and later steadies.

Smooth muscle is stimulated, and laryngeal and bronchial spasm are not uncommon. The drug is contra-indicated in the dental chair in bronchospastic states. Secretions are not increased.

Thiopentone is non-toxic to parenchymatous organs, but since it is destroyed in the liver, care is needed in hepatic disease. Relaxation of peripheral muscle is good. Its action in stimulating plain muscle may cause reflux of stomach contents if this organ is not as empty as it should be.

Buthalitone

This is chemically very similar to thiopentone, but has some alterations to the chemical grouping of the molecule. It is made available under several trade names of which "Transithal" and "Baytenal" are two examples. It was thought that it was more evanescent than thiopentone, and that recovery was even more rapid, making it better for outpatient use. Recent work has shown that this is not the case, and that it has no advantages over thiopentone, and some disadvantages in that it is less easy to judge the dose, and hiccoughs are common. Otherwise its pharmacology is similar to thiopentone's.

Pethidine

This is not often used in outpatient work, but nevertheless has some place in supplementing nitrous oxide. It is a synthetic analgesic and sedative which can be given by mouth, intramuscularly, or intravenously. The dose via the first two routes is 50–100 milligrams, and intravenously is rather less—about 20 milligrams.

It produces analgesia with euphoria, and addiction is an ever-present danger. The respiratory centre is depressed and so is the vasomotor centre, if given intravenously. Nausea is not uncommon.

There is little direct action on the heart, and the pulse remains unaffected. Bronchial muscle is relaxed by the drug and pethidine is a good agent in bronchospastic cases.

It is almost non-toxic and is excreted in the urine. It has an atropine-like action in relaxing smooth muscle, but there is no action on skeletal muscle. Pethidine releases histamine when given intravenously, and thus will produce a flare around the vein, with later phlebitis and thrombosis unless it is diluted to a strength of not more than 10 mgm. per ml. It is subject to the Dangerous Drug regulations.

ORAL PREPARATIONS

Barbiturates

They are all derivatives of barbituric acid. They are not as quick-acting as thiopentone and they are normally given by mouth, though some are given per rectum or by injection. Some hundreds of the compounds are known, and many are prepared for pharmacological use. They can best be classified according to their duration of action, but for premedication for dental surgery only the shorter acting concern us.

Examples of longer acting drugs are:

phenobarbitone	24–30 hours
barbitone	18–24 hours

Examples of shorter acting drugs are:

$$\left.\begin{array}{l}\text{quinalbarbitone (seconal)}\\ \text{pentobarbitone (nembutal)}\\ \text{sodium amytal}\end{array}\right\}\text{2–6 hours.}$$

They produce sleep but no analgesia. The response to pain is unmodified or it may be exaggerated because self-control is lost. The

respiration is depressed (but very little in normal doses) and the blood pressure is unaffected. Vomiting is rare.

Barbiturates are detoxicated in the liver but traces of the longer-acting drugs may appear in the urine. There are no toxic actions but occasionally they produce a drug rash.

Summary

In normal doses (for pentobarbitone, quinalbarbitone, and sodium amytal, 1½–3 grains) they have no significant pharmacological actions apart from sedation, no contraindications and no ill-effects.

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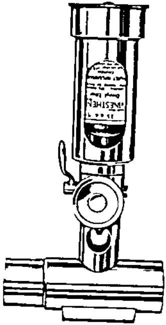
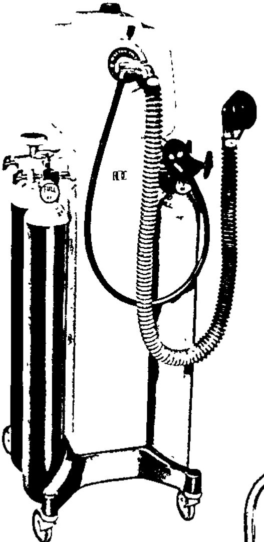
CHAPTER THREE

Apparatus

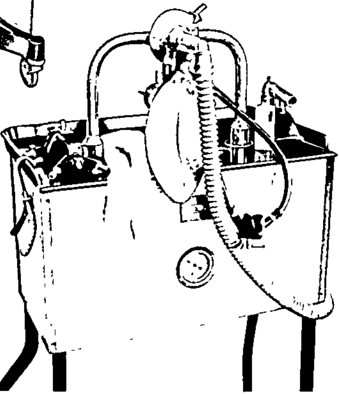
NITROUS oxide and oxygen are usually administered for dental purposes from a machine of the intermittent-flow type. The essential features of this class of apparatus are that it is capable of delivering a gas mixture of constant composition at a range of pressures from 0 to about 30 cm. water, and also can be set, if required, to deliver the mixture only when there is a negative pressure in the outflow pipe. The practical significance of this is that the machine can be made to have the composition of the mixture delimited by setting only one control, while a second control alters the pressure at which the gas is delivered and in consequence the gas flow. When the machine is set to require a negative pressure to deliver the gases, or is arranged to give them at a small positive pressure it becomes effectively an intermittent-flow device delivering gas only during inspiration, and shutting off the flow entirely during expiration. This mechanism not only conserves the gases but also prevents rebreathing when used in conjunction with a conventional one-way expiratory valve. In the design of intermittent-flow machines it is necessary to provide for very high *peak* rates of gas flow at the height of inspiration. In the average adult this may attain 40 litres per minute during a brief instant. In nitrous oxide anaesthesia the depth of breathing is increased so this figure of 40 litres will be considerably exceeded. Correspondingly high flow rates are delivered when the machine is run to give a continuous flow at positive pressure. One machine (Walton Mk. 2) was found to give between 35 and 45 litres per minute under anaesthetic conditions when set to the halfway pressure, and flows of up to 100 litres per minute are not unknown. Clearly these machines can consume large quantities of gases if mishandled, and it is common experience that cylinders have to be changed a great deal more frequently when using intermittent-flow machines at positive pressure for dental anaesthesia, than when using continuous flow machines in the operating theatre.



Goldman's Vinesthene drip-feed

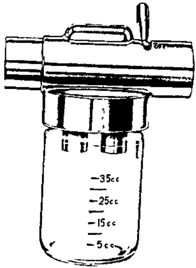


Walton Mk IV intermittent flow, gas-oxygen machine.



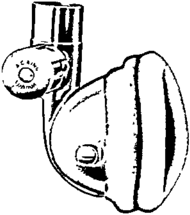
Walton Mk II gas-oxygen/gas-air machine

Vinesthene inhaler, Oxford pattern, modified Goldman's

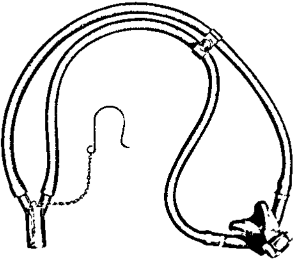


Rowbotham's vaporiser.

Guedel rubber oro-pharyngeal airway.



Goldman's pattern nasal inhaler



Nasal inhaler.

Continuous-flow machines, of which the Boyle is perhaps the best known example, are not very suitable for dental chair anaesthesia for the following reasons:

1. They must be used with a reservoir bag, in view of their limited flow rates, and some degree of rebreathing is inescapable. This slows induction, and means that the precise mixture being inhaled is not known, lying somewhere between that delivered by the machine and that of the expired gases.

2. Alteration of the mixture requires the adjustment separately of the oxygen and the nitrous oxide valves, a difficult manœuvre during dental anaesthesia, when the anaesthetist's hands are often fully occupied, and lacking the speed and convenience of the single lever of the intermittent flow types. In dental anaesthesia the mixture breathed by the patient must be critically and accurately adjusted and requires several fine alterations during the anaesthetic, if possible anticipating changes in the depth of anaesthesia. There is not the time to make the necessary mental arithmetic involved in calculating what changes are necessary, say, in a gas mixture of 10 litres nitrous oxide and 1 litre of oxygen, to alter the mixture to contain say 7% oxygen; whereas in an intermittent-flow machine the mixture is read in percentage direct from a dial.

3. Continuous-flow machines are not designed for high flow rates, or to provide positive pressures at the flow meter bobbins and it becomes necessary for the patient to produce an appreciable negative pressure to suck his inspired gases through the rather narrow tube connectors to the nasal mask. This is uncomfortable and can give rise to a feeling of suffocation. If there are any places around the mask which are not air-tight, the suction will cause dilution of the mixture from air leaks. The intermittent-flow machine has a sufficient reserve of pressure to overcome the resistance of the tubes during inspiration, and hence there is no feeling of resistance to inspiration by the patient and there will be no air leaks. There is a considerable pressure gradient from machine to patient when these narrow tubes are used which is unimportant when this gradient is overcome by the machine, but is too great to be coped with by the patient unaided. This is one reason why all tubing connected to the low-pressure side of continuous-flow machines has to be of relatively large bore, and if this proviso is maintained nitrous oxide can indeed be given very successfully from such a machine, which is the usual procedure using

a face mask and wide-bore tube. The Goldman nasal mask has been developed to eliminate the narrow bore tubing of the standard mask, and with this a continuous-flow machine can be used with more success.

There are several proprietary makes of intermittent-flow machines which are all very suitable for dental work. Some of the better known in this country include the Walton, McKesson, and Jectaflow, and all work on the same basic principles.

Nitrous oxide and oxygen are led from their respective cylinders to a regulator valve for each gas. Regulators are devices for producing a constant and relatively low pressure of gas in their outflow pipes, irrespective of the cylinder pressure or flow rates over wide ranges. They work upon the principle of admitting gas from the cylinder into a small chamber, one side of which contains a diaphragm connected to a needle or similar type of valve, either directly or via a series of levers. When the pressure in this chamber rises to a pre-determined figure the valve cuts off the supply of gas. The outflow from the regulator is taken from this chamber A powerful spring is incorporated in the link between diaphragm and valve, both to enable the low pressure to be adjusted at will, and to hold it constant, otherwise it would vary as a constant proportion of the cylinder pressure which would be determined by the mechanical advantage of the linkage, diaphragm and valve. This would be undesirable since the secondary pressure would fall as the cylinder became exhausted. When the spring is added the secondary pressure becomes a function of its force, rather than of the cylinder pressure

The outflow from the regulator valves is at about 5 lb. per sq inch in the Walton and other machines using Endurance or Reliance regulators, and is higher, about 60 lb. per sq. inch, in the McKesson machines. Normally the regulators are entirely automatic and trouble free in operation, and are silent They can be adjusted, but this must be left to the manufacturers, since unskilled meddling can lead to danger of failure from the high pressures in the cylinders, and an imbalance between nitrous oxide and oxygen will throw the machine's calibration out of balance.

The McKesson has pressure gauges connected to the low-pressure side of the regulators of both gases. These are not calibrated in actual pressures but show a normal range, with "Low" and "High". As they are on the low-pressure side of the regulator they *do not*

give any indication of cylinder contents (until these contain only a few breaths more gas) and are useful only as indicators that the regulators are working properly and that the cylinders are turned on. The Walton gauges are connected to the high-pressure side of the regulator (except the nitrous oxide in the older machines), i.e. they show cylinder pressure which is a true measure of the cylinder contents for the oxygen (which is in the gaseous phase in the cylinder).

Since nitrous oxide is stored as liquid in equilibrium with gas, the pressure in N_2O cylinders remains constant until all the liquid has evaporated and only gas remains in the cylinder. With 200-gallon cylinders sufficient remains to give one more anaesthetic after the gauge starts to fall.

In some Walton models there are two oxygen and two nitrous oxide cylinders. Since the gauge gives ample warning of running out of the oxygen there is only one regulator valve for this gas, and care must be taken not to turn on both cylinders at the same time, because the purpose of having two cylinders is that one shall be in use and one in reserve. If both are turned on at the same time, gas will flow through their common connecting piping until the pressures in the cylinders are equal. Thereafter gas will be drawn from both, and the pressure in each will fall simultaneously until both are empty at once, and there will be no reserve.

The position in these machines is different with regard to the nitrous oxide cylinders. There is no method (short of weighing) of ascertaining the contents remaining in the cylinder, and accordingly each cylinder has its own regulator, one labelled "running" and the other "reserve". In use BOTH cylinders are turned on at once, but since regulator valves are one-way devices no gas flows from one cylinder to the other even if their pressures are unequal. The regulator of the "running" cylinder is, however, set to deliver nitrous oxide at a very slightly higher pressure than the "reserve" regulator. Consequently as long as gas is delivered from the running cylinder the pressure from its regulator keeps the regulator of the reserve cylinder closed, and gas is drawn only from the running side. When this fails the secondary pressure drops below the cut-off pressure of the reserve regulator, and this cylinder now takes over the supply. This arrangement means that in effect the cylinders are used consecutively and two cylinders' supply will ensure that the nitrous oxide does not fail during an anaesthetic. The running cylinder will

become covered with frost, since it is cooled by taking up the latent heat of evaporation of the liquid from the cylinder and surrounding air, and so long as the reserve cylinder remains at room temperature it can be taken that it is not being used. When it too becomes coated with ice it is time to remove the running cylinder, which will be empty, to change the reserve cylinder to the running yoke, and to place an unused cylinder in the reserve position.

In all machines the low pressure gases are led to a further regulator device consisting usually of a rubber bag or a metal bellows. When the pressure in the bag rises to about 40 mm. Hg its expansion moves a lever which works a simple pinchcock and shuts off the supply from entering the bag. These rubber bags are mounted in the machines close to one another and are mechanically linked by rods or a series of levers so that the pressure in the two is identical. The precise linkage varies in different machines.

The position now is that relatively large volumes of nitrous oxide and oxygen are available at pressures approaching those of the physiological range, and absolutely equal. From each bag a wide-bore outlet runs via a non-return valve to a mixing chamber. The size of the respective orifices from the bags to the chamber is controlled by a simple slot device. As the pressures are equal the adjustment of relative sizes of orifices provides an accurate and constant method of selecting the anaesthetic mixtures delivered from the machine, and the mixing chamber slot is connected to a handle working over a dial calibrated directly in percent nitrous oxide and oxygen.

The method of turning on the machine also varies, but the principle is to override the mechanism admitting gases to the bags, raising the pressures therein, and causing gases to flow to the mixing chamber and on to the patient.

Some machines have an additional range to which the mixture may be set, allowing nitrous oxide to be given with air instead of with oxygen. This mixture is obtained by passing the nitrous oxide through a Venturi tube, and permitting the entrainment of air. This mixture has little application nowadays except for the production of analgesia, and is often omitted from the more modern machines. The device is not suitable for giving "gas and air" anaesthesia, since this is best done by lifting the mask from the patient's face.

Some of the McKesson machines have a rebreathing attachment in which rebreathing up to a pre-set and adjustable maximum volume

is permitted, against the pressure of a firm spring. Whatever the merits of this device it has no place in dental anaesthesia and should be locked closed when the machine is used for this purpose.

Cylinders

The pressure in nitrous oxide and oxygen cylinders rises with increasing temperature, so they should not be kept in a hot place or near a fire. Previously it was necessary to keep nitrous oxide cylinders warm because the gas contained water as an impurity and this froze in the outlet valves, but the gas now is perfectly dry and heating has not been necessary for many years.

When fitting a new cylinder to a machine the valve should be loosened slightly before it is attached, to blow out dust from the nozzle. If this is not done, the dust may eventually choke the fine orifices in the regulators, and there is a risk of fire should the dust be inflammable, since it will meet oxygen or nitrous oxide at high pressure, and spontaneous combustion is possible in certain circumstances.

Be respectfully wary of the high cylinder pressures involved, and take care when opening cylinders not to have the nozzle pointing towards the body. A sudden rush of gas may escape from a defective valve, and can disrupt a finger inadvertently held over the nozzle, or cause eye or facial injuries at some distance from the site of escape.

Other Apparatus

Beside the gas machine and cylinders, certain other apparatus is required for the administration of dental anaesthetics.

1. *Reservoir bag*. This is not essential but is a convenient accessory which is plugged into the machine's outlet. It can be compressed by hand during inspiration to increase inspiratory pressure in mouth-breathers, and this manœuvre is also the only effective means of giving artificial respiration, by compressing the bag with the machine supplying oxygen.

2. *Wide-bore Corrugated Rubber Tubing*. This should be fitted with the standard tapered metal ends so that it can easily be connected to the machine and at its distal end to nasal inhalers or a face mask. It should be 3 or 4 feet long. The anaesthetic machine connections are being made the subject of standardisation, and a new British

Standard is in preparation which will involve some change in existing connectors.

3. *Nasal Inhaler.* A standard oro-nasal inhaler is suitable. The nose and mouth-pieces are of moulded rubber, and the expiratory valve is attached to the nosepiece. The tubing mount has a swivel valve so that when the mouth cover is lifted a flow of gases is delivered to it. By dropping the mouth cover its gas supply is shut off.

4. *A set of anaesthetic face masks, with mount, connectors, and expiratory valve.* These are used when nasal gas is not practicable, as for example in young children, or for giving efficient artificial respiration with oxygen.

5. *A closed vaporiser for administering Vinyl ether.* The Oxford modification of Goldman's inhaler is suitable. It consists of a face mask mounted on a wide-bore tube connected direct to a 1-gallon rubber bag. Between the mask and bag is a chamber containing a piece of marine sponge, with a control lever and a series of ports so that the chamber can be cut out of the circuit.

This inhaler has no provision for the admission of fresh gases (except air) to the bag, nor for a carbon dioxide absorber to be used. Its use in consequently restricted to short anaesthetics.

6. *The Schimmelbusch Mask.* This is constructed of a wire framework designed so that it can be covered with gauze, and is made in appropriate sizes to fit loosely on the faces of adults or children. It should be covered with at least eight layers of surgical gauze, since lesser thicknesses let liquid anaesthetics fall through onto the face and even into the eye, and do not retain the air well enough to give a sufficient concentration of the inhaled vapour.

7. *Syringes.* These should be of suitable sizes for the drugs to be injected; 20 c c. will be needed for thiopentone, 5 c.c. for diluted pethidine for intravenous work, and 2 c c. or 1 c.c. for atropine. They can be sterilised in any way desired but dry syringes are the most convenient

8. *Airways.* These are not normally needed in dental work in the chair, but they may be necessary to establish an airway should a patient collapse and require the lungs to be inflated with oxygen. Guedel's rubber airways are best tolerated, and sizes three, two, and one will suit men, women, and children respectively.

9. *A laryngoscope and endotracheal tubes* should be available for emergencies, if the anaesthetist is able and accustomed to intubate the

larynx. The Macintosh laryngoscope is the easier for a beginner to use, and Magill endotracheal tubes, sizes seven, five, and one, will cover most emergency situations.

10. *A sterile emergency scalpel* should be kept in any place where anaesthetics are given, since it may be required to open the chest for cardiac massage, or for use in emergency tracheotomy.

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CHAPTER FOUR

Induction of Anaesthesia with Nitrous Oxide

THE art of giving successful nitrous oxide anaesthetics depends largely on the realisation by the anaesthetist of the fact that he is using an agent barely potent enough for his needs. Nitrous oxide is the normal agent used every day in this country for dental work because of its cheapness, its comparative safety, its freedom from unpleasant sequelae, its rapid recovery, its pleasantness, and the simplicity of the method of its administration. It is, however, a weak anaesthetic agent, and, as the oxygen with which it has to be administered to maintain life renders it more dilute, it is important that the patient's oxygen demand is kept as low as possible. One of the most effective ways of doing this is to keep him calm and quiet; a few seconds spent in friendly reassurance and chat as the patient enters the room are well repaid by easy smoothness of the subsequent anaesthetic. Most people not unnaturally regard general anaesthesia as a frightening procedure, and a rough induction without reassurance can easily turn fright into panic. The student who is himself worried about his ability to administer the anaesthetic may find it difficult to assume the calm confidence which means so much to the patient, but if he can succeed in so doing, he will find the results gratifying.

Preparations

Before arriving in the dental surgery the patient must have the opportunity to empty his bladder. Neglect of this simple precaution is sometimes followed by its involuntary emptying during anaesthesia, particularly in children This is an embarrassing incident for all concerned, especially the patient who has the journey home to face. It must not be allowed to arise.

The patient should be questioned about his last meal. The stomach must be empty before anaesthesia and the anaesthetist must not allow himself to be persuaded into giving a general anaesthetic if this

proviso is not satisfied. A full stomach renders the patient liable to vomit during and after the anaesthetic, and this places him in serious risk to life from inhalation of the vomit. Seated in a chair he is poorly positioned for immediate clearance of the vomit from the mouth, and this is a most dangerous accident. It is dealt with in detail in Chapter 9.

The average emptying time of the stomach after a full meal is 4 hours. It is lengthened by pain, fear, or excitement, and may be much longer in children. Any or all of the above factors are likely to be present in patients about to have a tooth extracted, so *at least* 4 hours must elapse after a full meal before the patient is anaesthetised. Do not be lulled into a false sense of security by the relative rarity of vomiting under nitrous oxide.

Many patients do not appreciate the vital necessity of their giving a correct answer to questioning about when they last ate. Parents particularly do not seem to regard as food, cakes, chocolate, buns, icecream, etc., eaten by their children, and close questioning sometimes reveals an enormous food intake continuing right up to the moment of visiting the dentist, all dismissed airily as, "Oh no, he has had nothing since his breakfast"!

A light easily digested meal, not less than 4 hours before the extraction, is the ideal. Prolonged starvation produces no good effects and the patient is more likely to feel faint after the operation.

Discretion may be used in respect of fluids taken before operation as they are normally retained in the stomach for shorter periods than solids. Beware, however, of milk which clots in the stomach and must be treated for practical purposes as a solid.

The patient should be asked to loosen any tight clothing which is likely to cause respiratory embarrassment. The commonest offenders in this respect are tight collars and corsets and belts.

The anaesthetist must satisfy himself that the patient is fit for operation and anaesthesia. This is discussed fully in Chapter 8.

The anaesthetic machine must be checked before use, particularly to ensure that the cylinders are full and connected to their correct yokes Do not test or connect the machine in the presence of the patient, the sudden blast of gas from a faulty valve is not conducive to calm and repose. Remember that while a failure of the nitrous oxide is embarrassing, failure of the oxygen supply, or wrong

connection of cylinders has been in the past, and may still be, the cause of patients' deaths. Take no chances!

It is essential that another woman be present when female patients are being anaesthetised. Some patients have erotic dreams under anaesthesia, particularly under "gas", and may imagine that they have been assaulted while unconscious. They may later make accusations against the operator or the anaesthetist, and the only sure way of averting an unpleasant situation is to have another woman present during the whole time the patient is unconscious.

Position

The patient should sit comfortably in the chair with the head and neck slightly extended, and the hands clasped lightly together in the lap. When the dental examination has been completed and the operator has inserted the prop, lose no time in starting the anaesthetic. It is uncomfortable to sit for minutes with the mouth propped wide open while the machine is being assembled. Some patients find the insertion of the prop the most unpleasant part of extraction under general anaesthesia, and this can be mitigated by reasonable speed once it is in place.

Absolute quiet must reign during the induction; for a sudden loud noise just as he is going to sleep may be misinterpreted by the patient and cause panic and a turbulent operation. Remember also that the sense of hearing is the last to be lost. Many anaesthetists and surgeons have had the embarrassment of having repeated to them an injudicious remark made while they thought the patient was asleep

The operator must not stand over the patient with forceps poised, as many patients close their eyes early in induction and open them later. The sudden sight of the extractor apparently about to start work not unnaturally causes alarm For similar reasons no one should be allowed to touch the patient during the induction.

The Induction

Set the machine to deliver pure N_2O Turn on the gases to about the halfway mark on the pedal on the early Walton machines, or about 15 cm. of water on those with measured pressure Stand behind the patient and hold the anaesthetic nose piece the right way, with the valve upwards—just above and about 1 inch away from his nose. At

the same time tell him to breathe normally and quietly through his nose. After three to four breaths the patient will have become accustomed to the flow of gas and its odour, and the mask should be gently but firmly lowered on to the nose to make a gas-tight fit. It must not be so high up on the face as to block up the nostrils and perhaps press on the eye, nor so low as to press on the nose and permit air leaks. The student should himself try breathing oxygen through a mask: this is the most effective way of showing him how to hold it and how to maintain a gas-tight fit.

At this stage the expiratory valve must be fully open. Nothing gives a greater sense of suffocation than to attempt to expire against pressure. Doubters should try for themselves.

Once firmly in place, the mask should be kept quite still and held with one hand only. To reassure the patient, explain that the hiss of the expiratory valve is just what is wanted. Throughout the induction the anaesthetist should maintain a line of patter which tells the patient what is expected of him and what is about to happen. The subjective sensations of induction are strange and may be frightening and the feeling that the anaesthetist is in contact with the patient and is looking after him makes a great difference to the latter's peace of mind.

After a few breaths of anaesthetic a calm patient will pass into a dreamy state where he loses touch with reality and becomes very suggestible. The skilful anaesthetist will realise this and use the opportunity to suggest repose and sleep with such words as, "You are just about to go to sleep—breathe through your nose and let yourself relax." Many patients are at first tense and frightened and can be seen to relax in response to such a suggestion.

Early in induction there is also a compulsive sense of irritation, making the patient fidget in the chair and attempt to settle himself more comfortably This is probably the result of early cerebral hypoxia. Later on he may make purposeful movements, such as raising an arm or shaking the head. These are usually intended to show the operator that the patient is not yet asleep, and if the anaesthetist realises this, he should further talk to the patient with remarks such as, "I know you are not yet asleep and we will not start until you are quite ready. Just put down your arm and breath the gas." A few such words at an appropriate time may avert struggling which could otherwise ensue

connection of cylinders has been in the past, and may still be, the cause of patients' deaths. Take no chances!

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Many patients have unpleasant memories of being held down while a child, and "smothered with gas". This is almost certainly the result of lack of care or interest by the anaesthetist during induction.

Some patients under the stress of the moment are unable to think clearly enough to bring thoughts and actions into line and to breathe through their nose. Particularly so is this true of less intelligent people, and often much explanation and exhortation must be used to secure nasal breathing. Any breath taken through the mouth will weaken the gas and prolong induction. Induction with "gas" should be entirely pleasant, and as long as there is no resistance to breathing, there is no feeling of suffocation.

Mouth-breathing is perhaps the most difficult barrier to good anaesthesia, as they are mutually incompatible. The patient cannot be allowed to mouth-breathe and if exhortation and encouragement are insufficient, two devices remain to be used.

Firstly, cover the mouth with a pack held in the hand sufficiently firmly to stop air leaks. This will be tolerated by the patient after a few breaths of gas, particularly if it is explained that it is to help him breathe through his nose.

Secondly, tightly cover the mouth with a rubber mouth-piece delivering a supply of gas. This must be applied firmly to stop all air leaks. Some models incorporate an expiratory valve which is intended to add to the patient's comfort, but in practice both types are tolerated equally well.

The vicious circle of mouth-breathing leading to lightening of the anaesthetic leading to further mouth-breathing must be broken; once surgical anaesthesia has been established the normal airway is nasal, and at this level the patient will nearly always breathe through his nose without further ado.

Signs of Anaesthesia

It has been said in jest that there are only three stages of anaesthesia: awake, asleep, dead. More prosaically in nitrous oxide anaesthesia the patient is either too light, in surgical anaesthesia, or too deep and jactitating. The well-known and "classical" stages and planes of anaesthesia were described in relation to open ether anaesthesia and have little application to nitrous oxide–oxygen.

Stage 1 is the induction with the patient awake but with a diminished

on. The mask is held off the nose while the anæsthetist talks to the patient to reassure her

The correct position of the anæsthetised patient. The head is inclined backward, while the anæsthetist holds the mask firmly on to the nose by traction on the tubes. His hands are placed to give support to the lower jaw

Preparing to insert the mouth pack Note the position of the right hand holding the mask in place, while the left hand is about to insert the pack.

pain sense—the state of analgesia—which can be made use of clinically as described in Chapter 11.

Stage 2 is delirium. The patient is unconscious but delirious and may be struggling. This should be passed through so quickly with nitrous oxide that it is not noticed, and the patient goes directly to surgical anaesthesia. If the induction is mismanaged or prolonged, as by allowing mouth-breathing to persist, this stage of excitement may be encountered.

Stage 3 is that of surgical anaesthesia, in which all operations should be performed. It is classically divided into four planes, which do not concern us here, as with nitrous oxide alone without premedication it is impossible to proceed deeper than Plane 1.

Further administration of gas leads to Stage 4, that of respiratory and circulatory paralysis—an undesirable and dangerous state of affairs which is further complicated by anoxia and leads rapidly to death.

The approach of surgical anaesthesia is heralded by three cardinal signs with which the student must become entirely familiar.

Signs of Nitrous Oxide Anaesthesia

Automatic Respiration

This is the most reliable guide to the depth of anaesthesia, and though it is not the most prominent sign, it is the one on which the student will rely almost exclusively when he acquires experience.

It is heralded by a subtle change in respiratory rhythm and accentuation, from the purposeful and sometimes irregular breathing of induction to regular, stertorous respiration in which heavy forceful expiration predominates, making a characteristic sound in the expiratory valve. It is often accompanied by snoring which may be felt more easily than heard.

Do not be misled by the rapid panting which some patients make during induction, often accompanied by shrugging the shoulders. Although regular and forceful, this is a conscious attempt to cooperate and has not the stertorous quality of automatic respiration.

Jactitation

This phenomenon is muscular twitching, starting in the facial muscles, especially the orbicularis orbi, and spreading rapidly to the muscles of the hands and fingers, and thence to all muscles of the

Preparing to insert the mouth pack Note the position of the right hand holding the mask in place, while the left hand is about to insert the pack.

When surgical anaesthesia is attained the eyelash reflex disappears, the eyes which may have been voluntarily closed often open slightly, and the lid can be pulled upwards without resistance. The direction in which the eyes look is inconstant. They may be aimlessly roving, or, more commonly, are strongly deviated in one direction or another. This deviation is usually not conjugate and the eyes are clearly not those of a wakeful patient.

The size of the pupil is also inconstant in induction, but at the correct level of anaesthesia it will be small or only moderately dilated, while a widely dilated pupil is a danger sign of extreme anoxia.

The student must be warned against examining the eyes except as a final confirmatory measure when other signs suggest that the correct level has been reached. It is extremely irritating to the conscious patient to have his eyelid pulled back every few seconds; it is not only unpleasant to one doing his best to go to sleep, but it also plants the probably justified fear in his mind that the anaesthetist does not know whether or not he is asleep, and that the extraction may start at any moment. For the resulting commotion the anaesthetist has only himself to blame.

The more proficient the anaesthetist, the less does he concern himself with the eye signs.

The student may be perplexed by the patient who is apparently being correctly induced, but who remains awake and shows none of the signs of anaesthesia long after they could reasonably be expected. The explanation is invariably one or more of the following:

(*a*) After the previous case the machine has not been reset to deliver 100% nitrous oxide.

(*b*) There are air leaks around the mask or in the apparatus.

(*c*) There is a measure of mouth-breathing taking place undetected.

When these faults are eliminated, the induction will proceed in the normal way.

body. It is also found early on in the muscles of respiration, where it gives a jerky hesitant interruption to the automatic respiration described above Its cause is anoxic stimulation of the central nervous system and it is thus an indication of asphyxia and of too profound hypoxia. Detected early, that is when it has not spread beyond the face or hands, it is a useful sign of surgical anaesthesia to a beginner who has been misled over the onset of automatic respiration, but it must not be allowed to persist. Firstly, because in spreading over the skeletal musculature it results in violent clonic movements of the whole body which render the operation impossible, and, secondly, because it is a warning sign that permanent anoxic damage to the central nervous system is not far away. The remedy is to increase the oxygen in the inspired mixture.

Children jactitate early and violently and it often first appears as opisthotonus, or arching of the back, which makes the child arise from the chair and slip to the floor.

The beginner may have difficulty in distinguishing jactitation from the movements of those too lightly anaesthetised. The following table helps to differentiate between the two phenomena:

Jactitation	*Inadequate Anaesthesia*
Patient too deep and probably cyanosed.	Colour good.
Twitching and purposeless movements.	Movements purposeful as to remove the mask or pull the operator away.
Not related to the surgical stimuli.	Movements related to and initiated by the painful stimuli.
Usually no phonation, but may snore.	Often accompanied by phonation.

The Eye Signs

During the induction while the patient remains conscious, the eyes may look in any direction. They are conjugate, that is their visual axes are nearly parallel, and focusing and accommodation are normal. The patient appears to be aware of and looking at his surroundings.

At the same time the eyelash reflex is brisk, i e. the patient blinks if the lashes are touched and the orbicularis muscle contracts and resists if the upper eyelid is pulled back. Many patients close their eyes during induction

waits until frank signs of undue lightness or depth have developed, he will tend to overcorrect the mixture too late and the anaesthesia will "swing" alternately too deep and too light, and it may become out of control.

The Pack

When the anaesthetic is stabilised the mouth pack is inserted. This pack is an essential to dental anaesthesia and can in no circumstances be omitted, because its purpose is to safeguard the airway from foreign matter, particularly teeth and their fragments, blood, and saliva which may otherwise fall into the pharynx. It is quite insufficient to rely upon the operator holding the tooth in his hand—it may slip from the forceps, it may shatter with considerable force, or its removal may be attended by unexpected severe haemorrhage. The inhalation of a foreign body is a serious and usually avoidable accident which is discussed in detail in Chapter 9, and should it happen in the absence of a mouth pack there could be little defence against a charge of negligence.

The pack can be inserted by either the operator or the anaesthetist according to their preference. The operator is usually in the better position to do so from in front of the patient, but some anaesthetists prefer to place this vital safeguard themselves. The pack should be made of a piece of surgical gauze of single thickness, about 12 inches by 6 inches, and should be inserted by feeding it into the mouth with the fingers, and not previously rolled up in the hand into a ball. Its site is important, the best position being opposite the posterior part of the hard palate. If it is further forward it will impede the operator, and if further back will cause retching by touching the soft palate. It should be arranged as a complete barrier between mouth and pharynx.

The pack may indirectly help to obliterate the oral airway of a persistent mouth breather by approximating the posterior part of the tongue to the soft palate, which happens when the anterior portion of the tongue is pushed downwards by the pack, but it has its own particular dangers, including:

Obstruction of the airway by the pack itself slipping into the pharynx.

A pack too large, or wrongly placed, pushing the tongue backwards and causing obstruction.

CHAPTER FIVE

Maintenance of Anaesthesia with Nitrous Oxide and Oxygen

WHEN the induction is complete and surgical anaesthesia has arrived, oxygen will have to be added to the inspired gases in proportions which must be gauged within fine limits of accuracy. Too low a concentration will cause undesirable anoxia, and too high will lighten the anaesthetic and make operating impossible It is not possible to be dogmatic about the precise concentration to be added, which varies in individual patients and with the way the induction has been handled, but the anaesthetist must assess his patient and act accordingly. As a general rule the admission of 7% oxygen three or four breaths after automatic respiration has become established will be correct at the start of the operation, but if the signs of anaesthesia have been missed and the patient is showing widespread jactitation at the time of administering the oxygen there will have been established a considerable oxygen debt, and 7% of the gas will neither stop the jactitation nor relieve the anoxia. Such cases are best dealt with by adjusting the control to the desired setting, say 7%, and then giving a direct blast of oxygen from the emergency button for two seconds. This apparently unprecise and vague method gives good results in practice

The calibration between individual machines is barely accurate enough within the limits required and varies slightly from day to day, particularly in the older machines. The correct setting for any given patient will thus vary by a few per cent from one machine to another, and the precise optimum must be determined by the anaesthetist himself.

It is important to remember that there is a time lag of four to five breaths between setting the percentage dial on the machine and the new mixture being carried to the patient's brain by his blood stream. The anaesthetist must therefore try to anticipate his patient's requirements by at least this interval, an art which comes with practice. If he

at once loses "contact" with the patient, and loses touch with the progress of the anaesthetic.

The thumbs of both hands should be slid backwards along the gas tubing attached to the nasal mask until they grip the tubes between the thumbs and the zygomatic arches. Traction backwards on the tubes will then ensure that the mask sits tightly on the nose. By simply rolling the thumbs it can in fact be made to assume any desired position on the face, and can for example be momentarily lifted, as is required if "gas and air" anaesthesia is being given. At the same time this drawing back of the hands brings the fingers into the correct position behind the angle of the jaw to support the latter when lower teeth are being extracted, and to push forward the jaw to carry forward the tongue should this be pressed back by the operator, obstructing the airway.

It is important not to dig the fingernails into the neck, nor to press upon the carotid sinus Very considerable support and steadying may be required in a difficult lower molar extraction, and better purchase on the jaw can be given if the knuckles of the index fingers are bent. When upper teeth are being extracted the anaesthetist should apply counter pressure to the head with his chest or shoulder to oppose the dentist's initial upward pressure on applying the forceps. It may be necessary to stand on a stool to do this properly.

The Airway

It is essential that a clear airway be maintained during all the operative procedures. It may be obstructed in one or more of the following ways:

The mask may slip or be pushed up to cover and obstruct the nostrils.

The pack may fall into and obstruct the pharynx.

The tongue may fall or be pushed back to touch the posterior pharyngeal wall and obstruct the pharynx.

The larynx, glottis, or even trachea and bronchi may be blocked by a foreign body such as a tooth fragment, part of the pack, or blood.

The vocal cords may become tightly adducted in spasm.

Obstruction to the airway must be detected and diagnosed at once as it is dangerous and undesirable for a number of reasons.

The supply of oxygen to the lung and hence to the body is reduced, with consequent hypoxia, and similarly the removal of carbon

Failure to remove the pack or packs at the end of operation The late removal of a forgotten pack from a patient whose jaws are tightly clenched and who is obstructed may be onerous and difficult.

The pack may become soaked with blood and fail in its purpose. If this happens it must be changed for a fresh one, taking care that there is no pharyngeal soiling while this is being done.

The following precautions are advisable:

The person who inserts the pack should make it his particular responsibility to remove it, though no one is absolved from responsibility in this respect.

Not more than one pack should be in the mouth at any one time. If it becomes soaked it is to be changed and not merely another added.

Not to use marine sponges, particularly small ones, in lieu of gauze. They can easily become separated from the tape to which they must always be attached, and fatalities are recorded from time to time from their inhalation causing total obstruction of the airway.

That careful search be made in the mouth for tooth fragments at the time the pack is removed, and also for any extra gauze swabs which the operator may have used.

The mouth pack can be removed soon after the anaesthetic is stopped, and before consciousness returns. If there is much blood in the mouth, the patient's head must be held forward so that blood does not run into the pharynx.

The Operation

The operator can now begin his extraction, and the anaesthetist must take his hands away from the mask to allow him access to the mouth. Close retention of the mask on the nose is one of the maxims of dental anaesthesia, and one which many students find difficult. Accurate approximation to the face and an air-tight fit are quite essential for two reasons. Firstly, a loose mask permits air breathing which dilutes the gas and lightens the anaesthetic to a degree much greater than the apparent small size of the leak would suggest, and secondly the regular sound of the expiratory valve is the anaesthetist's main indication of the patient's depth and rate of breathing, and indeed, that he is breathing at all. If the mask is not held on sufficiently tightly for the expired gases to move the valve, the anaesthetist

Note the close and airtight fit of the mask. Air cannot enter the system and upset the balance of nitrous oxide and oxygen which the patient is breathing. The anæsthetist has control of the airway.

dioxide is hindered. The supply of anaesthetic to the body is impeded and that which is already in the brain is redistributed to the body fat and the anaesthetic becomes lighter, though the signs of this are hidden by the hypoxia.

The ineffectual respiratory movements cause venous congestion and bleeding, which are exacerbated by the accumulation of carbon dioxide.

In practice, in nitrous oxide anaesthesia the result of obstruction to the airway is hypoxia, often of dangerous severity, accompanied by poor operating conditions.

The usual signs of obstruction to the airway include the following:

1. Cessation or sudden diminution of the noise of the expiratory valve, providing the mask is tightly applied. Every breath must be heard and cessation of respiratory noise must be investigated at once.

2. Stridor, crowing, or similar noisy respiration indicates a partial obstruction.

3. "See-saw" movements of the chest and abdomen. The diaphragm is a more powerful muscle than the intercostals when they are working in opposition, hence ineffectual efforts at breathing produce this type of movement, in which the chest recedes as the abdomen is pushed out by the diaphragm and vice versa. It is vital that these movements are not mistaken for normal respiration.

4 Rapidly increasing cyanosis.

The treatment of the obstruction naturally depends upon its cause.

1. Adjust the mask correctly.

2. Check or ask the operator to check the position of the pack.

3. Pull the jaw forward.

4. If the pack has obviously failed in its duty and there is a foreign body in the larynx it must be removed using whatever is most suitable: the fingers, a swab, suction, forceps, and a laryngoscope if the anaesthetist is proficient with this instrument. A child can be held upside down and thumped on the back, when the foreign body may fall clear of the airway.

5. Spasm of the glottis is rare with nitrous oxide, and is always due to a foreign body, usually saliva or blood in the larynx. So long as there is no solid object in contact with the cords the spasm will pass of its own accord, although if necessary oxygen should be given as

Note the close and airtight fit of the mask Air cannot enter the system and upset the balance of nitrous oxide and oxygen which the patient is breathing The anæsthetist has control of the airway

Showing the patient prepared for extraction The anæsthetist's hands are well clear of the mouth and the extractor's field is clear.

Showing the correct position for the anæsthetist's hands The pack and prop are in place and the anæsthetist is able to apply counter pressure with his shoulder to the head if upper teeth are to be removed

described in Chapter 9. Laryngeal spasm may become troublesome when intravenous barbiturates are used.

Some confusion may be caused by the patients who, though apparently correctly anaesthetised, stop breathing soon after induction is complete although there is no obstruction. This happens in the nervous or in the over-cooperative patient who overbreathes in induction either from fright or in a misdirected effort to be helpful. Overbreathing washes out the carbon dioxide from the alveoli and blood, and this, the normal stimulus to the respiratory centres, then ceases to have effect. After consciousness is lost the stimulus to the centre is provided by hypoxia alone. When this is relieved by the addition of oxygen to the mixture there remains nothing to excite the respiratory centres and breathing stops until sufficient carbon dioxide is accumulated, or oxygen lack again becomes sufficient to restart the respiration. Provided a clear airway is maintained these patients start breathing again in a few seconds, and their condition remains good throughout.

Mouthbreathing

Persistent mouthbreathing after induction is usually the result of too light anaesthesia, and if the mouthpiece is re-applied and proper anaesthesia re-established, a wholly nasal airway will usually result. Occasionally a patient will mouthbreathe throughout the operation and this must be dealt with at once or the anaesthetic will be wrecked.

Three measures are available:

1. Applying the mouthpiece between the extraction of each tooth. This tends to become unpopular with the extractor.

2. Closing the expiratory valve and forcing the gas at least as far as the pharynx. This may press down the soft palate into contact with the tongue and make the mouthbreathing cease.

3. Spraying ethyl chloride on to the pack, about 3 ml. at a time. This is a safe procedure and is usually effective in maintaining anaesthesia.

It will be necessary to alter the setting of the oxygen control if the patient does not remain at the correct depth of anaesthesia. If jactitation persists, or cyanosis becomes too deep, the inspired oxygen must be increased, say to 9% and if necessary a further short blast of oxygen administered from the emergency button. If anaesthesia lightens the control should be placed to 100% nitrous oxide

for five breaths and then returned to a lower setting than previously. The commonest cause of lightening of anaesthesia is not a defect in the gas mixture but the result of inspiration of air, either from a loose mask or from mouthbreathing, and steps should be directed to remedying these faults.

Increasing the Oxygen

During the course of anaesthesia it is essential to increase steadily the percentage of oxygen given. After a very short time, 1 or 2 minutes, the patient will require 10% of oxygen, and if the anaesthetic is at all prolonged he will need 12, 15, or even 20% in the mixture. This involves resetting the mixture control at frequent intervals during the anaesthetic.

It is instructive to compare the inhalation of gas mixtures of low concentration of oxygen, and the breathing of air at high altitudes. A mixture of 90% N_2O, 10% O_2 has the same partial pressure of oxygen as the air has at an altitude of 18,000 feet (Haldane and Priestley). Aviation experience suggests that short periods at similar altitudes (or partial pressures) are not harmful to fit people

Duration of Anaesthesia

It should be possible with nitrous oxide–oxygen alone to maintain adequate anaesthesia in the average patient for 5–10 minutes, but in the resistant or the unfit this may have to be reduced to much shorter periods. The critical factor is the degree of hypoxia which has to be produced to accompany the anaesthesia, and the body's reaction to this hypoxic stress The longer the anaesthetic the less well will the patient feel afterwards, and since rapid recovery is one of the main advantages of nitrous oxide it is generally better to restrict anaesthesia to 4 or 5 minutes If a longer time is required and the procedure cannot be spread over two or more sessions it is better to accept the limitations of nitrous oxide and use one of the supplements discussed in chapter seven which will enable adequate oxygen to be given through the anaesthetic and to avoid the dangers of hypoxia.

It is wise to cease the anaesthetic should the patient start to sweat profusely, to develop a gasping respiration, or to lose colour without obvious cause, particularly if his colour becomes grey or the pulse irregular. These are all signs that the body is not tolerating the

hypoxia. There is little purpose in routinely giving oxygen at the end of a "gas", but should the patient's condition give cause for alarm the first action is to clear the airway, and the second is to administer pure oxygen to the exclusion of all other gases. This is best done through a full face mask, though a nasal inhaler is better than nothing.

When the operation has finished the mask should be removed and the pack, and if possible the prop removed as well. If the prop cannot be removed because of muscular spasm at the end of the operation, it must be left until the patient has recovered consciousness. Attempts to remove it by pulling before he is fully awake can have two results: teeth will be damaged or displaced, and the patient will mistake the removal of the prop for the extraction, and will afterwards claim that he felt the tooth coming out.

The patient's head must be held forward until he is awake, to prevent blood gravitating to the pharynx. Do not assume that once the anaesthetic is over the patient can be left to recover on his own. It will be necessary to maintain his airway, to talk to him and if necessary to restrain him until he becomes fully orientated. The longest dental nitrous oxide–oxygen anaesthetic should not require the patient to remain in the chair for more than about 2 minutes if all is well and no supplements have been used. The patient should be assisted from the chair and allowed to sit quietly until fully recovered, and it is important not to leave him alone for this period as he may feel faint and fall, or remain disorientated and injure himself. An adult patient should be neither nauseated nor dizzy, and should be ready to walk from the surgery within 10 minutes. Occasionally a patient will require longer, and children are more often nauseated than adults, but if an anaesthetist's patients are frequently prostrated after nitrous oxide anaesthesia he should re-examine his technique!

No patient who has had an anaesthetic should drive a motor vehicle that day.

Reference

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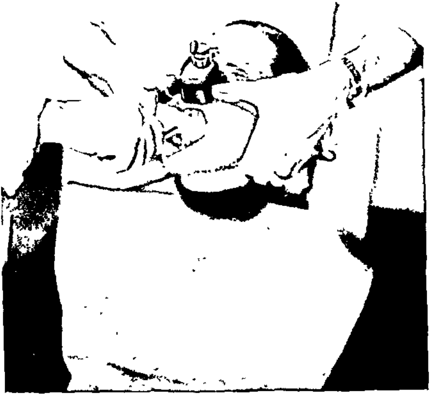
CHAPTER SIX

Children

THERE is no unusual difficulty in anaesthetising children for dental extractions, but by virtue of their mental and physiological immaturity the technique used for adults has to be modified in some details. They are a challenge to the anaesthetist because they can be frightened much more easily than adults and they have less self-control. On the other hand they can be the most rewarding of patients if sufficient trouble is taken. They may need a great deal of reassurance, and this should be started by a friendly approach from the moment they enter the room.

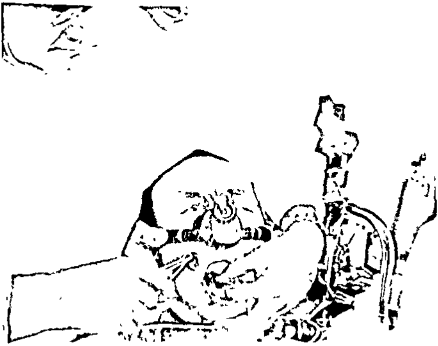
In general it is preferable that their mothers do not accompany them to the chairside; the anaesthetist can meet them at the door and explain that their mother will be waiting for them in the next room This arrangement is desirable both for the child, who usually behaves better if tactfully and kindly handled by strangers, and for the mother Most mothers undergo great strain when their children are having treatment and some become tense and emotional. If they are allowed to be present during the anaesthetic and operation they may distract the anaesthetist or operator, and their anxiety is only too easily transmitted to the child It is an unfair burden to expect any mother to witness an extraction on her own child. In rare instances the only method of persuading the child to enter the surgery may be to let the mother come too, but she must agree in advance to leave at once on the anaesthetist's instructions as soon as the child is asleep. If the father or a relation can bring the child to the surgery so much the better.

In private practice the child will usually know the operator, and often the anaesthetist too. What is about to be done should be explained to the child in language suited to his years. Most children make wonderful patients and do their best to be co-operative—far better, in fact, than many adults A short enquiry into previous anaesthetic experience will elicit any particular dislikes the patient



In this coloured (Lascar) patient is seen the correct position for supporting the jaw during a lower extraction. Note the pack behind the tooth, protecting the air passages

Extraction of lower teeth on the right side The anæsthetist holds the mask in place by the thumbs pressing on the tubes, while supporting the chin with his hands The deviation of the patients' eyes is typical of correct nitrous oxide anæsthesia.



[illegible]

yet been inserted

This child has been anæsthetised by placing [illegible]

mask has been used

The patient is anæsthetised for a major dental surgical procedure The anæsthetist is inserting the pack which is being held above the patient's mouth by an assistant The nasal endotracheal tube is in position See p 67.

has acquired. He may for example have had a rough induction the time before, and if he can be reassured that he will be gently handled this time he may be satisfied and happier. It is not uncommon for older children to volunteer that they have had "gas" before and liked the experience. This is a tribute to their first anaesthetist, and he who first anaesthetises a child has great responsibility to ensure that the experience is not unpleasant. First impressions count for much, not only in children, and as it is unlikely that the first will be the only anaesthetic the child will ever have, it is of the utmost importance that he views his return visits if not with pleasure, at least not with dread.

From the anaesthetist's point of view it is convenient to divide children into those who can and those who cannot by virtue of their age be anaesthetised with nitrous oxide and oxygen. The beginner will find that five years is about the critical age for deciding this, but with increasing experience he will be able to give nitrous oxide to children of half this age, or less. There are difficulties. Firstly the child's co-operation may be lacking, and thus nasal induction is made difficult; and secondly, the margin between anaesthesia and over-dosage, with hypoxia, is very small, the result of the instability of the nervous system of the young, and their small blood volume and rapid circulation which make a child awake one moment, and violently jactitating and hypoxic a few seconds later.

For the older child the procedure is precisely as for adults, with some modifications:

1. Talk to the child the whole time, explaining every step in advance. An easy line of patter can be developed, and makes all the difference in securing the child's acceptance of induction. Explain that the prop is to keep his mouth open so that he will not bite the dentist. If he objects to it, do not persist as it can be inserted later. Pretend that the nosepiece is a pilot's oxygen mask, or any fancy that comes to mind—that the gas is a magic wind to send him to sleep, etc. Some anaesthetists who have the knack or the practice tell the child a story during the induction, and he is asleep before he realises it The successful anaesthetist will be he who develops a line of patter for children and is not embarrassed to use it. There is an element of hypnosis about this.

2. Do not let anyone else talk to or touch the child. Some nurses

will try from the best motives to chatter to the child, or to restrain him, but the results which ensue are contradiction and muddle.

3. Do not rush to put the nosepiece on the face. Nitrous oxide is heavier than air, and with a good flow of gas, anaesthesia can be induced without the mask touching the face at all. Children questioned after anaesthesia will say that what they resent most are the mask pulled on to their face and the rush of gas up their nose. Neither are necessary.

4. Anaesthesia supervenes rapidly—children are asleep in five breaths, anaesthetised in ten, and violently jactitating in fifteen, so it is most important to be very generous with oxygen. In proportion to their size the metabolic rate of children is higher than in adults, and 10% oxygen is not too high for the beginning of maintenance in a five-year-old The jactitation of a child usually starts with opisthotonus, the child rises from the chair on his heels and head, and operating is impossible.

5. Err on the side of lightness, and do not regard phonation in itself as indicating inadequate anaesthesia. Children are more deeply anaesthetised by nitrous oxide than is at first apparent.

6. It is advisable to add 5% oxygen from the start of induction. This slows induction a little, but prevents the rush to profound anoxia which the very young show when induced with pure nitrous oxide, and makes for smoother anaesthesia. To avoid the slightly prolonged induction which this causes some anaesthetists give nitrous oxide alone for the first three breaths, and then add 5% oxygen whether or not the patient is asleep, adding the full quota of oxygen when the signs of anaesthesia develop.

7. After extraction is over remove the pack and prop at once if possible. Use more reassurance during the recovery, and it helps to give strong suggestion too, such as that he has had a pleasant dream and enjoyed himself When the child is conscious it is kind to take him straight to his parent

Children who are too young for nitrous oxide present a slightly different problem. The two most suitable agents are vinyl ether, sold commercially as Vinesthene, and ethyl chloride. Vinyl ether is to be preferred as it is safer, not having the cardiac depressant action of ethyl chloride, but its smell is horrible. Induction with either of these agents is far from pleasant, and because of this it is better to use

nitrous oxide as much as possible. Vinyl ether is best given by a closed method such as the Oxford inhaler, using a face piece.

The inhaler is filled with the contents of a 3 ml. phial of vinyl ether, and then turned to "off". The mask is slowly but firmly applied to the child's face. He will at first inhale through the non-return valve and exhale into the bag, and when this latter fills he will rebreathe from the bag. Talk to the child all the time. Every three breaths the inhaler dial is advanced half a division, waiting after every advance for the respiration to become regular. When the maximum setting has been attained keep the inhaler applied for not more than 15 seconds of deep regular respiration. Next the mask is removed and the pack and prop inserted. There will be full anaesthesia for about 1 minute. If longer time is required apply the nose piece and administer nitrous oxide and oxygen in 85:15 percentage.

The following details are important:

1. Once the mask is applied it should not be removed or air leaks allowed. This is not a kindness to the child as it only prolongs induction.

2. Do not continue for more than a quarter of a minute at most with the mask in place after anaesthesia has arrived. There is only a limited dose of drug in the apparatus and further delay after it has all been absorbed will result in the brain concentration being lowered by the blood redistributing it to the rest of the body.

Ethyl chloride is an agent as potent as vinyl ether but with the disadvantage that overdose is much easier, and that it is a potent heart toxin. Consequently care must be taken to ensure that too high a concentration is not inhaled by accident. It is best given on an open mask. 2 or 3 ml. should be sprayed on the mask before this is held near the patient's face. The child's hands must be held and struggling averted as well as possible by patter and conversation. When the child is breathing regularly further doses of the drug are sprayed on the mask which is slowly brought to touch the face. Plenty of air must be allowed to pass around as well as through the mask, and it is imperative that if the child holds his breath, no more be sprayed on to the mask until he breathes again. If more anaesthetic is given throughout a breath-holding episode, the next breath taken (which will certainly be a very deep one) will then contain a very concentrated vapour, perhaps sufficient to cause immediate cardiac arrest. The drug should be given with a circumspection similar to

that when chloroform is administered. The mask must be removed after a quarter of a minute's deep regular respiration, and again about 1 minute's anaesthesia will result. Delay in removal will give too profound anaesthesia, as more will be absorbed from the mask with each breath. Should overdosage arise the treatment is to remove the mask, and to inflate the lungs rhythmically with pure oxygen, using a face mask and bag. The signs of overdose are cessation of respiration, wide dilation of the pupils, and grey pallor to the skin. The last two are the result of its toxicity to the heart. Ethyl chloride has no advantages over vinyl ether except that it is slightly more pleasant to inhale, and is cheaper.

The Difficult Child

Most children of an age amenable to reason can be persuaded to accept anaesthesia peacefully by gaining their confidence, but the occasional child is encountered who is not accessible to explanation and talk, and who cries and screams from the moment he enters, or refuses to enter the room. The cause of this behaviour usually lies in spoiling by parents, or pain and loss of sleep, or previous unpleasant experience of anaesthesia or dental treatment.

The best treatment for such children is to give premedication, using drugs to calm them and make them drowsy so that they are less aware of their surroundings when brought to the chair. The advantages of this procedure are:

1. That they are more pleasant to handle for all concerned, and there are no unseemly struggles.

2. Anaesthesia is brought nearer by the premedication, so it can be achieved more easily with nitrous oxide, which can be given with an adequate concentration of oxygen for long enough in most cases for the whole mouth to be attended to at one sitting.

3. The children are often amnesic of the whole procedure.

4. Other patients are not upset by screams, an important consideration in a children's clinic.

There are unfortunately disadvantages, which are chiefly:

(*a*) They are drowsy for some time afterwards, and need transport home.

(*b*) The action of oral premedicants is not constant, and some

children are more or less affected than would be expected, so it is not possible to guarantee any given degree of sleep or amnesia.

(*c*) The drugs used sometimes cause postoperative restlessness, and some supervision is required from the parents or nursing staff.

On the whole the advantages far transcend the drawbacks. The best premedicants are the shorter-acting barbiturates, and it is recommended that the anaesthetist familiarises himself with not more than two or three of the drugs available, and sticks to them. Among the better drugs for this purpose are quinalbarbitone (Seconal), and pentobarbitone (Nembutal).

Suitable doses for either of these drugs are:

Ages 3–8 years	$\frac{3}{4}$ grain 1 hour before operation
Over 8 years	$1\frac{1}{2}$ grains 1 hour before operation

Do not use them for children under three years, and when in doubt modify the dose to the weight of the child rather than its age in years, i.e. a well-grown seven-year-old might need $1\frac{1}{2}$ grains, while a puny nine-year-old child would do better with $\frac{3}{4}$ grain.

The occasion will arise when the use of premedication will be impossible, either because the child refuses to take the tablet, or because he cannot be assured the postoperative care he needs. The only solution is to admit him to hospital or nursing home for full premedication and anaesthesia.

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CHAPTER SEVEN

The Resistant Patient

THE anaesthetist will find that there are classes of patients for whom nitrous oxide–oxygen is not sufficiently potent an agent for him to use alone and secure satisfactory anaesthesia. These patients can be classed as "resistant" and several types are well known.

Alcoholics and drug addicts. These persons are accustomed to taking large doses of analgesic drugs, or alcohol which is a very similar agent, and their central nervous system is accustomed to a more or less continuous blood "anaesthetic" level.

The very muscular or very fat. This habitus is not infrequently complicated by some measure of chronic alcoholism, as for example in the intemperate labourer or the fat publican. Any movements which they make under anaesthesia are correspondingly more violent than those made by normally built persons and are more difficult to control. Their respirations are of greater excursion and give opportunity for air leaks around the mask during induction, while the blood volume which has to be saturated with gas during induction is greater than normal, making induction slower and the excitement stage prolonged. Finally, in the obese with their jaw hidden in fat and less accessible, it is more difficult to hold and maintain an airway.

The very frightened whose co-operation is more easily lost. Their nasal breathing is difficult or impossible to establish, their fright raises their secretion of adrenaline, increases their metabolic rate and hence their oxygen demand, and prepares their body for fight—an emotion which becomes manifest as soon as consciousness is lost. Apart from this they may start movements during induction to show that they are still awake, movements which persist and become exaggerated when unconscious.

The dental anaesthetist should quickly learn to identify probably resistant patients before rather than after starting the anaesthetic.

Consciousness persists despite high concentrations of nitrous oxide, and if the "gas" is pressed it is superseded eventually by jactitation and struggling. They cannot be anaesthetised by nitrous oxide alone. In this situation discretion is most surely the better part of valour, and one of the methods to be described below should be used to secure quiet and satisfactory anaesthesia.

Premedication

The administration of sedative drugs before operation will bring the patient some of the way along the road to anaesthesia before the anaesthetic proper is given. Less is required of the nitrous oxide and a smooth anaesthetic results. Good premedication includes the following:

Alcohol for those who are accustomed to take it to excess. The patient should be instructed to take twice his normal "dose" 1 hour before entering the surgery. This must of course be consumed as an undiluted short drink of spirits. It is most unwise to suggest or permit a stomach full of beer, which would only be vomited and perhaps inhaled. For similar reasons, never deprive an alcoholic of his usual solace before any operation, dental or otherwise, unless there are definite medical indications for doing so. It is not the time to start a "cure", particularly as he will naturally be nervous and require more than ever the relief which he finds in liquor!

Barbiturate drugs. As in the case of premedication for children, the anaesthetist should familiarise himself with two or three only. Suitable ones include Seconal and Nembutal in doses of 1½–3 grains. This will make the patient drowsy before and after the operation and should only be given to patients who are accompanied by friends and who can go home afterwards.

No patient who has received any premedication is fit to drive a motor vehicle that day.

The Use of Additional Anaesthetic Drugs at the Time of Operation

Several are in common use.

1. *Thiopentone Sodium* (Pentothal)

This is an intravenous anaesthetic which is in widespread use in the operating theatre, but needs some modification in technique when given in the chair. With the patient seated comfortably, place a

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The dental anaesthetist should quickly learn to identify probably resistant patients before rather than after starting the anaesthetic.

It is not unknown for those who have received the drug to assure the anaesthetist that they are alert and feel well enough to go home, but later have no memory of the journey. They are in fact quite unsafe to be allowed to be unaccompanied and the anaesthetist might be held responsible at law for any acts committed by a patient in this state if he has not taken adequate care to have him looked after.

(*b*) Thiopentone increases laryngeal irritability, and saliva or blood in the larynx may provoke troublesome laryngeal spasm. The drug must NEVER be given without the immediate availability of a cylinder of oxygen and a tightly fitting face mask and reservoir bag, so that oxygen can be administered under pressure should laryngeal spasm or undue respiratory depression follow its use. It is a most dangerous practice to give a large dose of thiopentone for dental extraction (or any other operation), relying on the profound depression which it can cause to mask its lack of analgesic qualities. The hazard is increased if this is done by the single handed operator-cum-anaesthetist without the means of oxygenation to hand.

(*c*) There are some patients in whom it is contraindicated. (See Chapters 2 and 8.)

Despite these disadvantages it is probably the best adjuvant for the resistant case if the anaesthetist is skilled and if adequate postoperative care is possible. It has, however, been truly said that it is "fatally easy to give".

2 *Pethidine*

This should also be given intravenously, though oral or intramuscular routes are possible. A suitable intravenous dose is 25 mgm. in 2·5 ml. of distilled water, given 5 or 10 minutes before the anaesthetic The drug produces a pleasant euphoria, and should be followed by a conventional nitrous oxide anaesthetic. Some patients are nauseated, postoperative drowsiness is common, and it may cause syncope. It has few advantages over thiopentone.

3. *Trichloroethylene*

This drug is marketed in this country under the trade name of "Trilene", and is added to the gases from a standard anaesthetic machine by including a vaporiser such as Rowbotham's between the machine and the reservoir bag.

Technique. The patient is induced with nitrous oxide in the usual way, but when consciousness has been dulled, say after ten breaths

loose tourniquet around the arm to obstruct the venous blood flow and to render the veins prominent. Insert the needle into the chosen vein, avoiding the medial side of the cubital fossa where anomalous branches of the brachial and ulnar arteries may run superficially and can be entered by mistake. It is best to use a 2½% solution, i e ½ gramme in 20 c.c. of water. The dental prop is then put in place and immediately 6–8 ml. of the drug are rapidly injected, and the tourniquet released. This method will ensure that a small dose of the barbiturate (0·15–0·2 grammes) will rapidly enter the general circulation and in 10 seconds or thereabouts will reach the brain and induce sleep. Thiopentone has little or no analgesic action, particularly in these small doses, so it must at once be followed by nitrous oxide in the usual way before the extraction is started. If the operator does not wait for this, the patient although asleep will move and react strongly to the painful stimulus. The technique described ensures the maximum effect from a small dose, with the quickest recovery. Slow injection will result in the brain concentration being lower for a given dose, so will require larger doses to be effective, and will prolong the recovery time.

The dose recommended above is considerably less than that commonly used for major surgery in the operating theatre, and it will be noted that the strength recommended accords with modern practice. 2½% solution has the following advantages:

1. The irritant nature of the solution is reduced, and the hazards which follow its accidental perivenous or intra-arterial injection are much reduced

2. There is a lower incidence of thrombophlebitis with weaker solutions.

3. Accidental overdosage is less easy as the bulk of the solution limits the rate at which it can be given.

Thiopentone provides a pleasant induction for those who fear the mask, and will quell the most resistant patient. It has unfortunately certain dangers and disadvantages of its own.

(*a*) The recovery time is prolonged. The patient may need to be kept in a recovery room for an hour after the operation, as drowsiness and disorientation are the rule rather than the exception. He will often need transport home, he MUST be accompanied, and should not drive a car that day. The disorientation should be regarded seriously.

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the control of the vaporiser is moved a little at a time to the half-way position, a manœuvre which should occupy the time of at least ten breaths. Too rapid increase in vapour strength causes coughing and breathholding, and is unpleasant to the conscious patient. If these occur the control must be returned to "off", and then re-advanced more slowly. Oxygen is added in the usual way. Most vaporisers give too strong a vapour if turned more than half-on.

The signs of overdosage with this drug are rapid breathing and irregularities of the pulse, and with gross maladministration such as bubbling the gases through the liquid, cardiac arrest has happened When used as described trichloroethylene is a very safe, pleasant and useful additive to supplement nitrous oxide, and can be thoroughly recommended.

It is not only useful for the resistant, but it also allows the anaesthetic to be prolonged, with adequate oxygenation in the normal patient, should unexpected operating difficulties arise, or more time be required. Its use is far preferable to persisting with nitrous oxide alone and incurring undesirable hypoxia. It has a few disadvantages, which include slightly prolonged recovery and a little increase in the incidence of nausea Patients do not feel *quite* as fit afterwards as if plain nitrous oxide–oxygen had been used (although they are much fitter if given trichloroethylene than if kept hypoxic), but in any case escort home is rarely necessary Because of these drawbacks it is not generally advisable to use the drug in every case, whether or not resistant or difficult, although many anaesthetists in fact do this and find their patients well, their operating conditions good, and the anaesthetic easier to manage.

4. *Cyclopropane*

Some specialists use this in lieu of, or in addition to, nitrous oxide in the resistant case. It is rapid acting, pleasant, and potent enough to quell a resistant patient, while its administration with up to 80% oxygen is advantageous, but the disadvantages are legion and include its expense and its explosive potentialities. Recent work has shown that forceps slipping off a tooth may produce sparks of sufficient intensity to ignite cyclopropane, and there are other sources of ignition in the dental surgery such as gas or spirit flames, the switch and contacts of the engine, the X-ray machine, and the friction of the drill in the tooth if this is used during the anaesthetic

To reduce the explosion risk cyclopropane is now given with a mixture of 50:50 nitrogen-oxygen, or helium-oxygen with which it is not inflammable because of dilution, but this again increases the complexity of the apparatus. Finally the most compelling disadvantage is that many patients suffer from prolonged nausea, vomiting and malaise after its use, and it is really not suitable on this count alone.

5. *Ethyl chloride*

This can be given either by spraying in 3-ml. doses on to the pack in mouthbreathers—many resistant patients mouthbreathe—or by spraying it direct in similar doses into the reservoir bag of the machine. This requires a minor modification to the bag mount and the drilling of a small hole to permit the introduction of the drug without removing the bag.

If it is sprayed on to the pack this should be removed immediately the operation is finished, or absorption will continue and overdosage will be possible.

6. *Vinyl ether*

This is marketed commercially as "Vinesthene", and can be added to the gases from a Goldman drip vaporiser which is plugged into the anaesthetic machine. It is effective, but the salivation and the spasm of the jaw muscles may hinder the operator. The administration is not easy to control as vaporisation continues after the tap has been turned off.

7. *Halothane*

This recently developed agent has great promise in dental anaesthesia, but its cost—£10 per 250 ml. at time of going to press—is a disadvantage. It is pleasant to breathe, and should be added to the gases from a machine in a similar way to trichloroethylene. A vaporiser which gives a known and constant vapour concentration is ideal, and the "Fluotec" is suitable in this respect. The maximum concentration which should be given without atropine as premedication is 0·5%. In this strength the drug causes neither hypotension nor bradycardia.

Halothane is effective and controls a resistant patient very well, giving rapid recovery, with little hangover. Operating conditions are good and jaw relaxation is excellent.

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It is not only useful for the resistant, but it also allows the anaesthetic to be prolonged, with adequate oxygenation in the normal patient, should unexpected operating difficulties arise, or more time be required. Its use is far preferable to persisting with nitrous oxide alone and incurring undesirable hypoxia. It has a few disadvantages, which include slightly prolonged recovery and a little increase in the incidence of nausea. Patients do not feel *quite* as fit afterwards as if plain nitrous oxide-oxygen had been used (although they are much fitter if given trichloroethylene than if kept hypoxic), but in any case escort home is rarely necessary. Because of these drawbacks it is not generally advisable to use the drug in every case, whether or not resistant or difficult, although many anaesthetists in fact do this and find their patients well, their operating conditions good, and the anaesthetic easier to manage.

4. *Cyclopropane*

Some specialists use this in lieu of, or in addition to, nitrous oxide in the resistant case. It is rapid acting, pleasant, and potent enough to quell a resistant patient, while its administration with up to 80% oxygen is advantageous, but the disadvantages are legion and include its expense and its explosive potentialities. Recent work has shown that forceps slipping off a tooth may produce sparks of sufficient intensity to ignite cyclopropane, and there are other sources of ignition in the dental surgery such as gas or spirit flames, the switch and contacts of the engine, the X-ray machine, and the friction of the drill in the tooth if this is used during the anaesthetic.

Assessment of Fitness

NITROUS oxide and oxygen anaesthesia causes little or no pharmacological upset, and gives no physiological insult to the most frail of patients provided that it is given in suitable proportions to avoid hypoxia. If these provisos are filled, there is no contraindication to its use, and it is indeed well suited to major surgery in the very ill—though of course with other agents to enhance its potency. The conditions under which it is used in the dental chair do not, however, measure up to this ideal, and, except in special techniques described in Chapter 11, hypoxia of greater or less severity accompanies every dental "gas".

The more prominent of the changes in the body's "milieu intérieur" brought about by hypoxia are:

Reduction in arterial oxygen tension—anoxic anoxia.

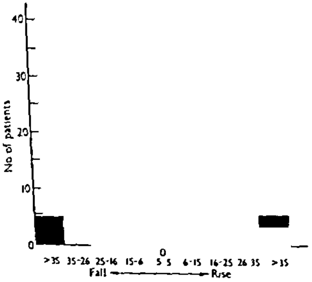

FIG. 2. Change in pulse rate after anaesthesia with $N_2O_2-O_2$ in 100 patients.

Its wider application awaits a simple and reliable vaporiser which can eliminate the very real risk of overdosage—and a reduction in price.

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CHAPTER EIGHT

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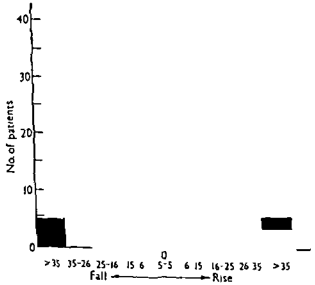

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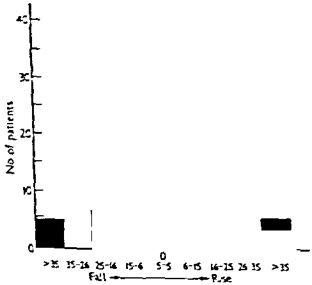

FIG. 2. Change in pulse rate after anaesthesia with $N_2O_2-O_2$ in 100 patients.

Rise in blood pressure, pulse rate, and cardiac output.
Secretion of adrenaline.

The changes in pulse rate and blood pressure in normal people under nitrous oxide and oxygen are shown in the accompanying graphs.

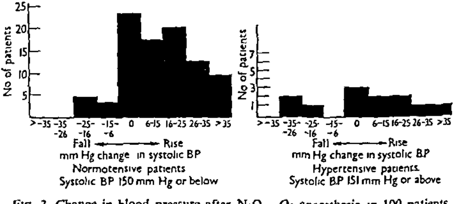

FIG 3. Change in blood pressure after $N_2O_2-O_2$ anaesthesia in 100 patients (Figs. 2 and 3 previously published in *Brit. J Anaesth.* **30**, 581, 582.)

It is these changes which place the strains on all the tissues of the body and which are responsible for any ill effects of "gas". Pre-existing pathology, particularly in the C.V.S. and nervous systems, will exacerbate the ill-effects of hypoxia and it is with such pathology, and these physiological changes in mind that patients are assessed when fitness for nitrous oxide anaesthesia is in question.

C.N.S. Disease

Cerebral arterial disease is the most important as it is a process in which there are degenerative vascular changes which reduce cerebral blood flow and oxygen supply. This may already be producing symptoms of its own, such as mental deterioration and decreased powers of concentration, or there may be evidence of past acute damage such as a "stroke". Any further decrease in oxygen during anaesthesia may push the patient over the brink, and some of his already ill nourished cerebral cells will be permanently destroyed. The most highly organised cells, those of the cortex, are the most susceptible to the reduction in oxygen tension and the less specialised tissues of the lower centres are more hardy in this respect. Various

limits of time have been described under which deprivation of oxygen is said to be safe, but these must not be misinterpreted as giving latitude for anoxia in anaesthesia; in any case they usually refer to the previously fit and well oxygenated brain. Cortical tissue can be chronically sub-oxygenated to the point beyond which there is no reserve, and the least further hypoxia causes irreparable damage. There is ample evidence of patients having permanent cerebral damage which can be directly traced to a hypoxic episode such as dental anaesthesia, and is most frequently recorded in the old. The damage varies from slight insidious deterioration in temperament to a complete dementia and a decorticate state; so cerebral vascular disease must contraindicate any technique involving hypoxia. Further danger lurks in the rise in blood pressure following oxygen lack, which may provoke cerebral haemorrhage from a weakened vascular tree. One should be very wary, therefore, of hypoxia in the old, and in those who have given unmistakable evidence of vascular disease of the brain in the form of a "stroke". These patients should not be given a conventional nitrous oxide anaesthetic, but should be anaesthetised with one of the techniques described in Chapter 11 which avoid hypoxia.

Other diseases of the C.N.S. which may cause doubts about suitability for anaesthesia include epilepsy of all types. Epileptics are easily and safely anaesthetised with nitrous oxide, but it is important that they take their usual dose of anti-convulsants. There is a slight risk that hypoxia may trigger off an attack during recovery and the anaesthetist should be prepared for this, though it is rarely met with. Should the patient's history suggest that this is probable, as for example may be the case where the fits are frequent and poorly controlled, anaesthesia should be induced with thiopentone and be maintained with nitrous oxide, the barbiturate being a potent anticonvulsant as well as an anaesthetic.

Mental defectives, and those suffering from mental illness present no particular problem providing their attention can be held during induction. Anaesthesia is sometimes held responsible by the laity, should it coincide with the onset of a psychosis such as schizophrenia, for causing the disease, and be blamed for the illness. There is no evidence that properly conducted anaesthesia has any causal relation to psychosis, and the idea is an instance of "*post hoc ergo propter hoc*".

Organic non-vascular disease of the C.N.S. is no bar to dental anaesthesia though the stress of operation may cause an exacerbation of multiple sclerosis. "Spastic" children are easily anaesthetised by "gas".

Cardiovascular Diseases

Coronary artery disease is the main pitfall. This is more of a problem than many forms of vascular inadequacy as it may be silent, and producing no symptoms. The patient who has had a frank attack of coronary thrombosis or suffers from angina pectoris is ABSOLUTELY UNFIT for nitrous oxide in the chair These diseases involve already severe myocardial sub-oxygenation, sufficient to cause infarction in the one and symptoms in the other. Further oxygen lack places the patient in peril of cardiac arrest and death during even short anaesthesia. Should such a patient require general anaesthesia he must be admitted to hospital and anaesthetised by methods which do not involve hypoxia, alterations in blood pressure or cardiac output.

Hypertension which is severe enough to cause symptoms (but not the mild symptom-fee hypertension often found in those over middle age) also renders the patient unsuitable for "gas". An additional rise in pressure may precipitate failure of a cerebral vessel, hypertensive encephalopathy, or myocardial failure.

Valvular disease of the heart, a relatively frequently encountered condition, is of as much importance *per se* as the underlying myocarditis and impaired cardiac reserve which may accompany it. The cardiac reserve, which is the capacity of the heart to perform extra work in response to stress is the most reliable guide of all to fitness for anaesthesia. The reserve is reduced in myocardial degeneration, in valvular disease where compensation is failing, and in ischaemic heart disease amongst others The state of the cardiac reserve can best be found by the patient's answers to a few simple questions. The adult patient who can perform the amount of physical work reasonably expected from one of his age, who can walk up two flights of stairs without stopping for breath, and who can run for a bus, is fit for nitrous oxide anaesthesia whatever the murmurs in his heart. His fellow who has to live on the ground floor because of shortness of breath, who cannot walk up a short hill or do a full day's work has a heart muscle which will not respond to the least call for extra work and is probably unfit for "gas" in the chair. These criteria are

valuable for their simplicity, as a few questions will enable the anaesthetist to elicit the relevant facts about the fitness of the patient's cardiovascular and respiratory systems. Physical examination of the patient is unlikely to add to the knowledge gained from this history, and can normally be omitted, unless the symptoms described above suggest otherwise. The room in the Royal Dental Hospital where extractions are carried out under general anaesthesia is on the third floor, and the ability of a patient to walk up to it is strong prima facie evidence that there is little wrong with his circulation.

Children, and sometimes adults, will be found who have had operations on the heart, or who are known to have congenital heart disease. They are not suitable subjects for outpatient general anaesthesia and should be admitted for full general anaesthesia in the operating theatre. The disease may cause cyanosis, or may be potentially cyanotic at rest, and such patients tolerate hypoxia very badly. The rise in pressure may cause extra-circulatory shunts to appear and the circulatory dynamics to be upset and perhaps put the heart into failure. Those who have had operative treatment for heart disease should also be admitted since it is often impossible to restore the heart's anatomy entirely to normal by surgery and the operation may indeed have been designed to produce further shunts as palliative measures, as for example in Blalock's operation.

It is appropriate here to remember the need for providing antibiotic cover before extracting teeth from anyone who has valvular or congenital heart disease. The danger is of course that the transient bacteraemia which follows extraction may be sufficient to start subacute endocarditis in such patients. Suitable cover is one million units of crystalline penicillin 1 hour before operation. Despite negative clinical signs any patient who gives a history of rheumatic fever should be given the same treatment.

Anaemic patients are on the whole fit for nitrous oxide, but *need great care* as it is very easy to make them dangerously hypoxic without there being any cyanosis to give warning, and such patients may mysteriously collapse from just this cause if the possibility is not borne in mind.

Respiratory Diseases

There are relatively few respiratory contraindications to dental "gas". Dental treatment is unlikely to be required in the acute

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after recovery. The same regime is to be followed when anaesthetising patients under treatment with the newer sulphonamide drugs such as tolbutamide. The major problem of anaesthesia in diabetes is the avoidance of hypoglycaemia, but with the short duration of dental anaesthesia this is of less importance than in prolonged surgery in the operating theatre. Should a diabetic require nitrous oxide to be supplemented as described in Chapter 7, almost any of the additives are suitable but cyclopropane and pethidine should be avoided as they may be followed by malaise and nausea, and upset the food intake afterwards. Diethyl ether is contraindicated as it causes a marked rise in blood sugar, but thiopentone, trichloroethylene, or halothane are very suitable.

Thyrotoxicosis

The severe thyrotoxic is not suitable for straight "gas", for her nervousness makes her a very difficult patient, her high B.M.R. causes increased demand and needs raised oxygen content in the gas mixture, and at the same time she requires larger doses of all anaesthetics than the normal patient—these are incompatible demands from nitrous oxide. The toxic myocarditis of the disease is another reason for discretion when hypoxic techniques are contemplated. Fortunately the widespread use of anti-thyroid drugs of the thiouracil and carbimazole type has totally changed the picture and the untreated severely toxic case is practically unknown nowadays. Even in them dental extraction can usually be postponed for the short time necessary for control of the disease Mild thyrotoxics can be safely anaesthetised in the chair but should receive heavy premedication such as 3 grains of Nembutal. Euthyroid patients controlled by drugs, those who have had surgical treatment, and those who are myxoedematous present no problem and can be treated as normal.

Cortisone

Now that Cortisone, Prednisone and allied substances are widely available, patients will be encountered who are taking these drugs, or who have had them in the past. Administration of these drugs makes the patient unable to respond to the stress of operation and anaesthesia, however trivial, by the increased adreno-cortical activity

infections such as the pneumonias. Bronchitis is no bar, nor is bronchiectasis providing it is not sufficiently severe to produce cyanosis and dyspnoea and that the patient is previously tipped to empty his chest of sputum over the short period of the anaesthetic. The chronic bronchitic and emphysematous man who is near heart failure or whose respiratory reserve is reduced so far to give dyspnoea at rest, is unsuitable. The anaesthetist should be wary of using thiopentone in asthmatics, though nitrous oxide is normally safe provided the patient is not in an acute attack. Thiopentone has a parasympathomimetic action which can exacerbate the spasm, and pethidine, a bronchodilator, is far preferable to use as an adjuvant in these cases

Healed and non-active tuberculosis presents no difficulty so long as it is not presenting symptoms simply from the destruction of much lung tissue. Active tuberculosis is also often no contraindication to "gas" though some physicians advise against it and the individual circumstances of the patient must be considered If cases of active tuberculosis are anaesthetised the apparatus must be thoroughly disinfected by boiling after use. Past treatment of phrenic nerve crush, pneumothorax or pneumoperitoneum, segmental or lobar resection, do NOT contraindicate nitrous oxide, though patients with a large maintained pneumoperitoneum or pneumothorax should not have this gas, because it diffuses very quickly into such air filled spaces, quicker, in fact, than the nitrogen diffuses out. In a short time the volume of gas in the space will increase and it may cause respiratory embarrassment.

Diabetes Mellitus

This should not worry the anaesthetist who plans to administer nitrous oxide alone The patient who is controlled by diet without insulin needs no special precautions except that it must be remembered that he will have the degenerative arterial changes common to all diabetic patients. The prescribed period of starvation before anaesthesia will improve rather than worsen his diabetes.

The patient taking insulin should not miss a meal but should have the extraction timed just before the next one is due, and he should take his normal diet and his usual dose of insulin. He should be given the advantage of a smoothly administered anaesthetic so that he does not vomit and can take his normal meal straight afterwards, or if this is not possible, the appropriate dose of carbohydrate in the form of a drink containing 25 grammes glucose or sucrose

CHAPTER NINE

Anaesthetic Emergencies

PATIENTS under anaesthesia sometimes show unexpected and alarming deviations from the normal smooth and safe path of unconsciousness, and require prompt and correct action to be taken to restore conditions to normal. The action to be taken is no different from that in any other branch of medicine when the unexpected happens—make the diagnosis and carry out the appropriate treatment, but there is the difference that the diagnosis has to be made at once on the spot, and there is no time to summon help or advice about treatment if the patient's life is not to be placed in grave jeopardy. There are nevertheless certain emergencies which are met with more frequently than others and it is important to be able to recognise them and treat them correctly.

Faults in the Apparatus

These will almost certainly arise because the machine has not been checked before use. Although this should be unalterable routine before every case, the very fact that it *is* a routine may lead to some check being omitted, or memory incorrectly relied on that some part or other is in order when in fact it is not. Typical errors are to find the oxygen cylinder empty or not turned on or the valve key missing, just when it is urgently required to deal with unexpected hypoxia. If this is accompanied by cessation of respiration the only measure possible if the oxygen supply cannot be restored within seconds is mouth to mouth breathing. A facepiece is held securely over the patient's face, the airway is cleared, and the lungs inflated by the anaesthetist rhythmically blowing into the open orifice of the mask. This inelegant procedure will cause the patient to be "aerated" with a mixture containing about 15% oxygen, but this is a great deal better than none at all and may tide over the emergency until the oxygen supply can be restored.

The breathing of a very high concentration of a volatile additive

normally found at such times. The result may be cardiovascular collapse during or shortly after operation.

If a patient is taking cortisone or a like drug, or has received it during the last year in full doses he requires a booster dose of 100 mgm. hydrocortisone by injection just before operation, even under out-patient anaesthesia. If extensive in-patient procedures are contemplated he must receive a full course of pre- and post-operative treatment with cortisone.

Surgical Conditions

Important are those involving hazard to the airway, and chief among them is Ludwig's Angina. This causes oedema of the larynx, glottis and tongue, and a severe case will be very toxic, hypoxic and cyanosed, and existing only on laboured respiration with the accessory muscles of respiration being used. Such patients are in immediate danger both from the disease and from misguided anaesthesia Thiopentone and plain "gas" are contraindicated. The latter adds a further and fatal element of anoxia and kills quickly—though thiopentone is fatal even quicker. This drug is a depressant of the respiratory centre and a direct depressant of the already toxic heart muscle. Unconsciousness causes loss of the voluntary muscles which have been used to make the respiration adequate, and hence almost simultaneous cessation of respiratory efforts and cardiac standstill. It is necessary to ensure an airway by intubation of the larynx under topical anaesthesia before consciousness is lost, and to oxygenate the patient thoroughly before anaesthesia is induced —for which cyclopropane is often used. The disease is one for the experienced anaesthetist alone, and is one of the most difficult to anaesthetise in the whole field of surgery.

This is dealt with more fully in Chapter 10.

Reference

BEDFORD, P D (1955) *Lancet* 2, 259, "The Adverse Cerebral Effects of Anaesthesia in Old People".

the available oxygen to the brain and the respiratory and vasomotor centres fail. The respiration ceases and blood pressure falls further with worsening cardiac output and further de-oxygenation of arterial blood. The onset is surprisingly rapid, and the patient's condition becomes alarming over the space of a few seconds. Almost the only other cause for the condition in dental chair anaesthesia is overdosage with ethyl chloride or thiopentone, which are directly toxic to the heart and produce primary cardiac failure.

Treatment. In the following order:

1. Stop the operation and discontinue the anaesthetic.
2. Clear the airway and remove the mouth pack and fragments from the mouth. There will be little bleeding.
3. Lay the patient flat on the floor or lower the back of the dental chair. This helps gravity to direct what circulation there is to the brain.
4. Change the nosepiece to a full face mask, close the expiratory valve, apply the mask tightly to the face, set the machine to deliver 100% oxygen either from the emergency control or via the usual gas valves, and rhythmically inflate the lungs by squeezing the reservoir bag 16 to 20 times per minute. It is essential that the chest be seen to move during this procedure, as it is easy to lose all the oxygen from leaks around the mask if this is not held correctly, or to distend the stomach and not the lungs. To ensure inflation it may be necessary to insert an oropharyngeal airway—a size two or three Waters or Guedel type is suitable.

This artificial respiration must be continued until the patient revives. Usually the colour returns after a few seconds successful inflation, followed almost at once by spontaneous respiration. Full recovery of consciousness may be slow, and the patient will require to be kept lying down for an hour or more, and must have transport home. This is the sort of accident which is liable to produce adverse permanent cerebral sequelae. It is a grave event even if all is apparently well afterwards, as hypoxia may produce brain damage which is only noticed in those who rely on their intellectual processes in their everyday life. This is particularly likely to happen in more elderly patients. Fortunately the body's recuperative powers are so good that permanent damage is rare, but recent work has suggested that permanent brain damage is commoner than was at one time thought.

due to the control being incorrectly set may produce a severe bout of coughing, and collapse if the agent has been inhaled in appreciable dose. Correct setting and inspection of the machine will prevent this, and some anaesthetists make a point of smelling the gases being delivered before each anaesthetic to ensure this has not happened. A happily rarer accident nowadays with the advent of non-interchangeable cylinders and valves is the connection of cylinders to the wrong yoke, but a similar hazard lies in failing to inspect machines after they have been dismantled or serviced in any way, since the internal piping, or snap-on rubber tube connectors may have been incorrectly replaced. It is probably as well to let no one touch the gas machine except the anaesthetist, the trained orderly, and the maker's engineers. The devastating effect of well meant cleaning and tidying by inexperienced nurses has to be seen to be believed. If any other gas emerges when the oxygen is turned on the consequences may very well be disaster. The natural reaction is to add more "oxygen" if the patient's condition deteriorates, and thus a vicious circle of maladministration is set up. The only path to safety in such an event is for the anaesthetist to have realised that such a possibility may arise, as the patient's condition deteriorates too quickly for the machine to be checked once things have started to go wrong The correct action is to abandon the machine if there is the least suspicion that this may have occurred, and let the patient breathe the atmosphere, the composition of which can be guaranteed to be sufficiently rich in oxygen.

Collapse

The patient who collapses under anaesthesia shows the following signs.

1. Cessation of respiration, or infrequent gasps.
2. Colour change to grey.
3. Widely dilated pupils.
4. Faint and irregular pulse.

These are symptomatic of circulatory and respiratory failure, and if not rapidly treated proceed to cardiac arrest and death. *The condition is almost invariably the result of too profound and too prolonged hypoxia.* A circle of events is set up—the heart's action is weakened and cardiac output is reduced; this still further reduces

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of twenty was anaesthetised while blood pressure records were kept for purposes unconnected with the individual anaesthetic. Early in induction he showed signs of collapse before he would be expected to be unconscious, and when he was not appreciably hypoxic. His systolic blood pressure fell to 60 mm. Hg, and his pulse slowed to 40 per minute, but on being laid flat he recovered within seconds. It is probable this was a faint. He was later anaesthetised in a recumbent position without incident, and the extractions completed.

Cardiac Arrest

This is the direst of all emergencies. It is extremely rare during out-patient dental anaesthesia, and those concerned are all the less prepared to take effective action when it happens. The cause is again almost always unwise hypoxia, though ethyl chloride or thiopentone overdose may be responsible. The initial symptoms are those of collapse, and a practical difficulty lies in determining whether the heart has in fact stopped. It is reasonable to assume that a case of collapse which does not respond within 30 seconds to the above treatment, and which has no carotid pulse after that period, has cardiac arrest.

Treatment. Only one thing is rational—cardiac massage. If the patient is to survive and retain his mental faculties his cerebral circulation must be restored by massage in the shortest possible time. The survival of cortical cells during total circulatory arrest depends on a number of factors, including their oxygenation immediately before the standstill, but it is unlikely to exceed 2 minutes, within which time the chest must be open, massage started and a circulation re-established. The intracardiac or intravenous injection of drugs is unlikely to succeed and the time spent doing this only delays effective treatment.

Technique Sterility is of *no importance* and an incision is made in the fourth or fifth left thoracic interspace, 8 inches long and stopping 1 inch from the sternum to avoid the internal mammary artery. There will be no bleeding The hand is insinuated through the ribs and the heart grasped and rhythmically squeezed 40 or 50 times a minute. The squeezing should produce a palpable carotid pulse, but care is needed not to perforate the heart with the fingers. If the other hand can be introduced to the chest and the heart compressed

(*a*) Do not leave the patient to summon help. To be successful treatment must be done by those on the spot.

(*b*) Do not delay inflation of the lungs for a moment **for any reason whatsoever.** Particularly not while looking for so-called analeptic or reviving drugs to inject. These drugs, of which nikethamide (Coramine) is perhaps the best known, are indeed powerful respiratory stimulants to the conscious patient They act indirectly on the respiratory centres of the brain by stimulating the carotid body chemoreceptors, and depend for their action on an intact reflex arc, and a respiratory centre which is able to respond to reflex stimulation Consequently their effect decreases as the central nervous depression increases, and they are **without effect** in the "collapse" under discussion The lesion is a simple lack of oxygen, and it is but sound physiology that this should be the first to be remedied, when if there is any circulation at all the heart and brain will at once respond. The injection of these drugs and their finding, preparation of syringes, seeking a vein, and sterilising the skin only delay, perhaps irrevocably, the oxygenation of the patient *It must be restated that they have no place in the treatment of emergencies in dental anaesthesia*

A specialist anaesthetist may find it advantageous to intubate these cases, but will not do so if it in any way delays inflation with oxygen.

(*c*) Do not use other methods of artificial respiration if oxygen and a mask are available, as they should be, since the respiratory exchange they produce is small.

Collapse under gas is a serious event which should never be allowed to happen The anaesthetist should regard it as a grave indictment of his technique.

Fainting

Recent reports indicate that there may be a further cause for "collapse"—a simple faint or vaso-vagal attack under anaesthesia, or even arising from fright while still conscious during the induction. The use of the erect position in the dental chair exacerbates this. Such patients, who may be young and fit, present similar signs to the above, though with pallor rather than cyanosis, and a slow pulse. The condition is as potentially dangerous if untreated as collapse from any other cause, but as it is circulatory in origin and not primarily anoxic it responds to lowering the patient flat. A young man

between the two hands, so much the better, but this is not essential. A mouth gag such as Mason's makes a good emergency rib spreader, and the squeezing must be maintained until the heart beats steadily on its own. During this procedure the chest and lungs must be rhythmically inflated with oxygen by squeezing the bag of the anaesthetic machine, and there is no need to be concerned about opening the chest when oxygen under pressure is available. Once the heart has started it must be watched to ensure that it does not fail again, in which case the massage must be restarted. The closure of the chest may be delayed until surgical aid is available.

A dental surgery is improbable surroundings to perform thoracotomy, but it may be possible to save a life in this way, while failure to perform cardiac massage will indubitably be followed by death, and it is denying a reasonable chance to the patient to refuse to do it. A scalpel is all that is required and one should be kept available in any place where anaesthetics are administered. Cardiac massage is a well-recognised procedure, and providing it is carried out at once has a good chance of success. Cases are even recorded where single-handed practitioners have revived patients without the benefits of inflation of the lungs with oxygen. The immediate dangers are few, and negligible compared with the possible benefits, and the remote problems, mainly of infection, can be dealt with later.

Following cardiac arrest or any other prolonged period of cerebral anoxia it is wise to take immediate steps to prevent cerebral oedema adding to and exacerbating the brain injury. The intravenous injection of 40 ml. of 50% sucrose is advisable at the earliest possible moment, and if necessary repeated. This may indeed be followed by the sudden return of consciousness, which is usually delayed after such episodes.

Vomiting

Vomiting is uncommon under nitrous oxide anaesthesia, and if it does happen it is usually early in induction, or late in recovery when the laryngeal reflexes are active and there is no danger of inhalation. Vomiting can also be provoked by pushing the pack too far backwards and thus irritating the soft palate, but usually this produces only a retch or two and the patient will then settle down. If true vomiting occurs the anaesthetic must be stopped, the head held well forwards or to one side and the airway at once cleared by swabbing

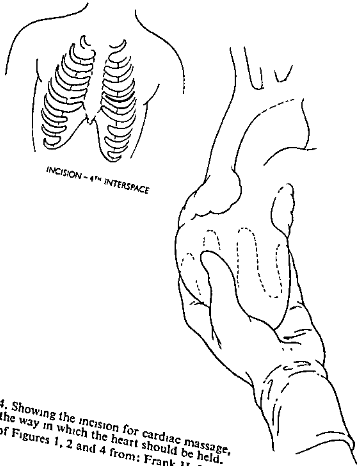

FIG. 4. Showing the incision for cardiac massage, and the way in which the heart should be held.

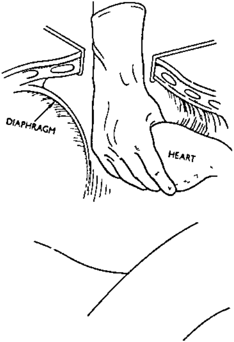

FIG 5. A diagram to show the technique of cardiac massage.

(Modification of Figures 1, 2 and 4 from: Frank H. Lahey and Edwin R. Ruzicka, *Experiences with Cardiac Arrest*, *Surg., Gynec. & Obst.*, 90, January, 1950)

that the suction machine is a powerful device such as a water or oxygen operated type. Some machines are incapable of producing enough vacuum to suck up semi-solid matter through the necessarily rather small tube, and may give a sense of false security—how false is shown only when they are most needed to perform.

If intubation is not possible the patient must be given postural drainage, lying with his head low and buttocks raised on a pillow, on his right and left side alternately for half-hour periods, and encouraged to cough. If he is cyanosed he must have oxygen to breathe.

A few drugs are of help once the above measures are proceeding. Aminophylline intravenously in doses of 0·25 grammes will reduce the bronchospasm associated with the inhalation of a foreign body, and digoxin 0·25 milligrams intravenously may be necessary if heart failure and pulmonary oedema occur. Atropine is useless, as the oedema fluid is a transudate and not an exudate.

The inhalation of a tooth fragment is usually less dramatic than the above, but it is extremely important that it is detected at the time, so in any case where a tooth fragment cannot be accounted for a careful search must be made. Often it will be found adhering to the mouth pack—and indeed inhalation should not arise if the pack has been correctly placed. If any solid matter cannot be traced the patient must be told what has happened and a plain X-ray of his chest and stomach arranged forthwith.

The commonest site for ingested foreign bodies is the stomach, and provided they are reasonably small no further action is necessary if they are found there. Fragments in the bronchial tree are an entirely different proposition. Usually their inhalation will have been heralded by a violent bout of coughing, which may expel them again, but the coughing wears off and a silent period follows. Occasionally there is no fit of coughing to mark the inhalation. Fragments of tooth or stopping in the lungs mean that the patient must be sent at once to a thoracic surgeon for their removal. Delay in doing so makes their subsequent removal through a bronchoscope difficult or impossible, as oedema of the bronchial mucosa soon follows inhalation. This causes the mucous membrane to swell so much as to obscure the object from view, or make its removal with forceps impossible.

The object must be removed, since its retention is followed by collapse of the lobe or segment whose bronchus it blocks, followed by infection, bronchiectasis, and lung abscess in the untreated case.

out the pharynx with a swab held in the fingers. During a properly given "gas" the reflexes should still be active, but if the vomit is the result of too profound hypoxia the reflexes may be depressed and danger of inhalation is real Great care must be taken in all cases of vomiting to clear the airway by positioning the head so that gravity will take the debris away from the airway passages. The properly prepared patient should of course have no food in his stomach but some patients may, by mistake or even by intent, conceal the fact that they have had food, while even the fasting stomach will contain a small quantity of resting gastric juice.

Inhalation of foreign body

Foreign bodies most likely to be inhaled are: vomit; tooth fragment or stopping; blood or saliva. The inhalation of vomit is serious and can cause sudden death either by total blockage of the airway by solids, causing death from asphyxia; or by reflex vagal cardiac inhibition resulting from the stimulation of the laryngeal and tracheal mucosa by irritant acid stomach contents If these hazards are survived, an inhalational pneumonia and acute pulmonary oedema can develop, complicated by areas of pulmonary collapse Unless actively treated they progress to bronchopneumonia and possibly lung abscess, with bronchiectasis as a late sequel Clearly, prevention is better than cure.

The treatment depends to some extent on circumstances. If solid debris blocks the upper air passages as far down as the larynx it must at once be removed either "blind" by swabbing with the fingers, or under vision using a laryngoscope, forceps and suction. The anaesthetic will of course have been discontinued and when the upper airway has been cleared the patient should be given pure oxygen to breathe until his colour is as good as possible. When this has been done the airway below the glottis must be cleared of vomit. If the anaesthetist is expert and a bronchoscope is available this should be passed at the earliest opportunity—but it is most unlikely to be practicable in the dental surgery—and the vomit removed by suction. It is more probable that the anaesthetist will be able to pass an endotracheal tube of which one or more of suitable size should always be available when anaesthetics are being given, as should be a laryngoscope. Suction via a suitable soft rubber or "portex" catheter blindly down the tube will remove a great deal of the vomit, but it is essential

that the suction machine is a powerful device such as a water or oxygen operated type. Some machines are incapable of producing enough vacuum to suck up semi-solid matter through the necessarily rather small tube, and may give a sense of false security—how false is shown only when they are most needed to perform.

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The object must be removed, since its retention is followed by collapse of the lobe or segment whose bronchus it blocks, followed by infection, bronchiectasis, and lung abscess in the untreated case.

If bronchoscopic removal is impossible an open operation and bronchotomy may be necessary.

Obstruction of the Airway

This is also dealt with under "administration of nitrous oxide" since some degree of obstruction is a problem which has to be solved in practically every anaesthetic and is usually due to some relatively minor cause such as the surgeon pressing back the jaw. If the simple procedures described in Chapter 5 fail, and the obstruction is at or above the cords and the patient's condition deteriorating, a tracheostomy must be made. Like cardiac massage, this procedure is only very rarely required and is all the worse prepared for because of this.

Equipment. A permanently sterilised tracheotomy set is the ideal but is rarely available and a scalpel is the only essential. No anaesthetic is needed and sterility can be neglected since the patient will be "in extremis".

Technique

1. Well extend the head in the chair, and if possible have an assistant to hold it steady.
2. Identify the thyroid and cricoid cartilages, and hold them with the left hand
3. Make a vertical incision 2 inches long strictly in the mid-line and below the cricoid. Place the hook, if available, under the lower border of the cricoid and draw it upwards to stabilise the trachea.
4. Make a vertical incision through the cartilaginous rings of the front of the trachea and insert the tracheotomy tube, or if not available the handle of the knife, and turn this through 90 degrees to hold open the trachea and keep an airway.

Bleeding will be profuse but will subside to manageable proportions when the respiratory obstruction is relieved and the great veins empty. There is little danger of injuring vital structures so long as the incision is kept in the mid-line. This is also a heroic operation and not to be undertaken lightly, but when all else fails it is life-saving. The necessary action must be taken by those on the spot—there is not time to summon outside help. Once again there is no point in temporising by injecting drugs and stimulants when the lesion is clearly one of respiratory obstruction The only useful course is to remove or bypass the obstruction by whatever means are available.

Finally, if any emergency has arisen *during an anaesthetic it is* unwise to alarm the patient by telling him that he "cannot take gas" or "must never have another anaesthetic," if the crisis was really the fault of the anaesthetist, for example failing to correct an obstructed airway, or depriving the patient of oxygen for so long that his circulation collapsed. These "warnings" to the patient are seldom based on fact, and whether partly justified or not they do nothing to put him in a happy frame of mind when he requires a general anaesthetic again at a later date.

If there is some valid reason for a patient being an unsuitable subject for a nitrous oxide anaesthetic in the chair this should have been discovered before, rather than after, embarking on such anaesthesia.

It is, however, reasonable to tell a patient who has been unexpectedly resistant that this has been the case. He will then be able to warn subsequent anaesthetists in time for them to arrange premedication, or to supplement their anaesthetic should they so wish.

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CHAPTER TEN

Major Anaesthesia in the Operating Theatre

PATIENTS can be admitted to hospital for major dental surgery because they need more after-care than can reasonably be given to an outpatient, or because the operative procedures contemplated are more extensive than can readily be tolerated in the chair or because they require more prolonged anaesthesia than can be given as an outpatient. Other benefits which may influence the decision whether or not to admit the patient for hospital treatment are the improved operating conditions which inpatient anaesthesia can provide Some patients may be admitted for reasons more connected with the anaesthetic than the operation, because they present anaesthetic problems in the chair or because they are unfit for the techniques normally used for outpatients

Premedication

The standard drugs used are very suitable, although it is well to bear in mind that it is undesirable for the patient to be unusually drowsy in the immediate postoperative period or to depress his laryngeal reflexes more than necessary. He will undoubtedly have blood in his mouth at the end of the operation and it is highly undesirable that this should be inhaled Suitable premedicants for adults include pethidine in doses of 50–100 milligrams together with hyoscine $\frac{1}{150}$ grain, or papaveretum (Omnopon) $\frac{1}{6}$–$\frac{1}{3}$ grain with the same dose of hyoscine. Pethidine has advantages where the subject is bronchitic or emphysematous, or gives a history of bronchospasm, as it relaxes the bronchial muscles, rather than opiates which have a bronchoconstrictor action The phenothiazines, of which the better known include promethazine (Phenergan), and chlorpromazine (Largactil), are best avoided, and so are the newer tranquillisers. Though suitable for operations at other sites they leave the patient too drowsy, and reduce laryngeal reflexes too much for use in dental operations. Morphine and atropine are also suitable premedicants.

These are not operations in which antisialogogues can be omitted, since the manipulations inside the mouth provoke troublesome salivation.

Dental inpatients are often children, and their premedication should be chosen with care. Omnopon and Scopolamine in the doses recommended by Dr. Anderson are extemely effective. The amounts given depend on the child's weight.

Weight	*Omnopon*	*Scopolamine*
28 lb.	$\frac{1}{8}$ grain	$\frac{1}{450}$ grain
42 lb.	$\frac{1}{6}$,,	$\frac{1}{300}$,,
56 lb.	$\frac{1}{4}$,,	$\frac{1}{200}$,,
70 lb.	$\frac{1}{3}$,,	$\frac{1}{150}$,,

Children under five can receive rectal thiopentone in doses of 20 milligrams per pound weight, i.e. 1 gramme per 50 lb. with a maximum dose of 1 gramme. This is given in 5% solution via a fine rectal catheter, and must be injected slowly over a period of 10 minutes while the child's attention is distracted by his being read to. He will fall asleep within a quarter of an hour and then he can receive his atropine without being aware of it ($\frac{1}{100}$ grain over five years, $\frac{1}{150}$ grain for two to five years, $\frac{1}{200}$ grain under two). The maximum depression is reached in three-quarters of an hour, and at any time after this the anaesthetic can be started. This is a good method but depends for success upon having nurses trained to the technique, and an unhurried approach.

As an alternative, the child can be given an oral barbiturate such as nembutal or seconal (0·6 grain per stone weight, with a maximum of 3 grains). The drug may be disguised in jam as its taste is unpleasant, since it must either be removed from the capsule or the capsule perforated to ensure uniform absorption. The action of oral barbiturates is less constant than premedication secured by other routes and for general purposes they should be avoided. This method has the additional disadvantage that restlessness and disorientation after the operation are common.

Induction

Normally in adults induction is with thiopentone, and again the use of 2½% solution has advantages (see Chapter 7). It is also very

suitable for children, and providing only "sleep" doses are administered it can safely be given to those who have received barbiturate premedication. The drug must NOT be given in large doses to such patients, because the premedication may not have had its full effect by the time the anaesthetic is given, in which case some time later the cumulative effects of both will be evident, with signs of overdosage.

Children who are asleep when they reach the anaesthetic room are best induced with nitrous oxide, which can usually be done without waking the child. By no means do all children fear "gas" or prefer an intravenous induction. Many, perhaps two-thirds of those under twelve, have strong objections to injections in any form and much prefer to have "gas," and a few find it definitely enjoyable. If they have been wisely premedicated they can be sent to sleep very pleasantly with nitrous oxide run from a mask held a few inches from the face. Children who have had previous anaesthetics will be able to tell the anaesthetist their preferences and should be given the induction of their choice. The personality of the anaesthetist is of the utmost importance (see also Chapter 6).

Maintenance

All cases should be intubated, and the nasal route is preferred because it leaves the mouth free for the operator. In the occasional patient who has nasal obstruction from a deflected septum or from any other cause, and who cannot, therefore, have a nasal tube passed without undue trauma or compression of the tube, the oral route must be used. Provided it is placed to one side of the mouth and can be moved during the operation it will not greatly inconvenience the operator. It is usual to pass the tube under the influence of a short acting relaxant such as suxamethonium (Scoline), which affords the best conditions for atraumatic intubation. Practised anaesthetists may prefer to use the "blind" intubation technique, and young children may have the tube passed without a relaxant when the anaesthetic has been deepened by ether or halothane.

The use of nasal tubes restricts the size which can be employed, but it is seldom necessary and is always undesirable, because of resistance to respiration, to use a tube smaller than No. 7 in a man and No. 6 in a woman. Spraying the nares with either 10% cocaine or ½% ephedrine in saline before the tube is passed will shrink and decongest the

nasal mucosa and reduce the risk of trauma and bleeding. This is particularly worthwhile in children who may have masses of friable adenoid tissue. Trauma to the nasal mucosa may make it swell and partially compress a thin-walled tube. This takes a few minutes to happen and may be the cause of otherwise unexplained respiratory obstruction arising during the course of the operation. It rarely happens if a decongestant is used.

The Pack

The pharynx must be well packed off, since the operation is invariably accompanied by bleeding which must be kept from the larynx and air passages. A cuffed tube is not a suitable safeguard. If it is passed through the nose, it will either reduce the size of tube which can be passed on account of the room taken by the pilot inflation tube; or if it is of the "streamline" type, the available free air passage will be smaller than in the corresponding uncuffed tube. A cuffed tube will do nothing to keep blood from the pharynx and from the larynx above the cuff, and it will be difficult to avoid tracheal soiling at the end of the operation if no pack is used. Also the cuff may burst.

The pack should be placed behind the tongue and surrounding the tube, well out of the surgeon's way. It may be made of the conventional gauze, which should be of full width and 18 inches long, and should be soaked in water, wrung out, and moistened with water-soluble lubricant It can be positioned either under vision with a laryngoscope and Magill's forceps, or "blind" with an assistant holding the pack and feeding it into the mouth, whence the anaesthetist, standing to the patient's side, will put it in place using his two forefingers. Whatever method is used it is important not to scratch the palate or pharynx since this causes postoperative discomfort out of all proportion to the trauma.

A simple and effective device, used at the Royal Dental Hospital, is made of two Tampax absorbent packs, tied together and inserted under vision into the pharynx where they are placed on either side of the tube. Since they swell when wet they provide a perfect barrier guarding the larynx, and they are easily removed. Whenever a pack is inserted the anaesthetist must be very certain that it is not forgotten, and some device such as an adhesive label on the patient's neck should be used as a reminder.

The anaesthetic agent can be whatever the anaesthetist prefers. No local analgesic should be used on the cords or tube, in view of the need to retain laryngeal reflexes at the end of the operation, so the anaesthetic must be sufficiently deep to prevent the patient coughing on the tube. Nitrous oxide and oxygen supplemented by ether, trilene or halothane is very suitable. Pethidine is not so good as it depresses laryngeal sensitivity, but in small doses it is frequently used.

At the end of the operation the pack must be removed, the pharynx sucked clear under vision, and the tube removed, by which time the patient should be sufficiently awake to cough He will probably need an oral airway, and he must be turned on his side, and remain in this position, until conscious, to let blood run out of the mouth rather than collect in a pool in the pharynx and air passages. Heavy postoperative sedation is rarely needed and is unwise. Opiates or pethidine are seldom required, and tabs. codein. co. will suffice.

Inpatient Conservative Treatment

Patients are occasionally admitted to hospital so that they may have full anaesthesia for conservative dental treatment which would normally be carried out in the chair, either with no anaesthetic or with local analgesia. They are usually older children who will not co-operate, or patients suffering from mental illness.

It is usual for the whole mouth to be treated at one session, which may be prolonged over some hours They present no anaesthetic problems except that premedication should err on the heavy side, and the anaesthetic should be conducted as described above.

Special Operations

As well as extractions, the dental anaesthetist will be required to deal with maxillo-facial injuries and other oral surgery, all of which can present formidable anaesthetic problems. There are certain operations in particular which have the reputation of difficulty.

Fractured jaw

This may be a relatively "cold" operation, undertaken some days or weeks after the injury, or it may be a part of a grave emergency complicated by *facial trauma, unconsciousness, intra-oral haemorrhage* and an obstructed airway.

The elective treatment of a fractured jaw usually presents few difficulties. The patient is prepared for operation in the usual way and anaesthetised as described. The intubation should again be nasal and, while a pack can be used if any intra-oral work is to be done at the same time, it is more customary for no pack to be used and for the fixation of the jaw to take place at the outset. The lower jaw is fixed by wires passed around the remaining teeth so that the "bite" and apposition of the jaw fragments are as close to normal as possible. The wires are left *in situ* for some weeks while bony union is taking place.

The main anaesthetic problem is the risk of vomiting after the operation, since it will be difficult to remove vomit from the mouth. The matter is best dealt with from the preventative angle, and it is advisable to administer some anti-vomiting drug with the premedication. Suitable drugs are promethazine (Phenergan), and chlorpromazine (Largactil), in oral doses of 50 milligrams on the morning of operation, or an intramuscular or intravenous dose of 25 milligrams 1½ hours before the operation. Both these drugs potentiate the narcotics in the premedication, which should be reduced to half the dose that would otherwise be used. Largactil has other side actions, including reducing the blood pressure, and it is recommended that Phenergan be used unless these side effects are required for other reasons. Pethidine is preferable to opiates in the premedication as these provoke vomiting in some subjects.

At the end of the operation the mouth should be inspected to ascertain whether there are gaps left between teeth which can be used to drain vomit, or through which it would be possible to insert a sucker. Usually there are one or more gaps but sometimes patients have a full dentition, even after the trauma of fracturing the jaw. The inspection will also reveal which wires it will be necessary to sever should it be necessary to open the mouth in a hurry.

It is more than ever necessary to keep the plane of anaesthesia as light as possible during these operations, so that at the end of operation the patient can be placed on his side and the tube withdrawn with him only just unconscious. Once the tube has been withdrawn the control of the airway may be difficult since an oropharyngeal airway cannot be used, and it may be wise to leave the tube partly withdrawn in the nose to act as a nasopharyngeal airway.

The anaesthetist should not leave the patient until consciousness

The anaesthetic agent can be whatever the anaesthetist prefers. No local analgesic should be used on the cords or tube, in view of the need to retain laryngeal reflexes at the end of the operation, so the anaesthetic must be sufficiently deep to prevent the patient coughing on the tube. Nitrous oxide and oxygen supplemented by ether, trilene or halothane is very suitable. Pethidine is not so good as it depresses laryngeal sensitivity, but in small doses it is frequently used

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patient whose mouth will be filled with blood clot and perhaps fresh bleeding as he is turned over for intubation. He will have to be assured that he can intubate the patient without delay in far from ideal surroundings when the usual landmarks have been obscured or displaced. Fortunately, intubation is usually easy once the larynx has been seen, since the shattered tissues do not resist the laryngoscope. A bronchoscope should also be ready in case there has been gross tracheal soiling, and if necessary bronchoscopy should be performed at this stage.

The question of the siting of the tube must be decided in co-operation with the surgeon in the light of the individual circumstances, but with intra-oral bleeding a cuffed tube is essential.

Some anaesthetists may prefer an inhalational induction because of the shocked state of the patient and the respiratory obstruction, and they may use cyclopropane or halothane to give unconsciousness and relaxation.

Once the endotracheal tube has been passed the immediate danger is over, but the problem of the full stomach remains and a large bore stomach tube should now be passed to empty the stomach of its contents.

The postoperative care is very important and constant skilled supervision is essential.

If there is a complicating head injury with depressed levels of consciousness the level of anaesthesia should be very light so that recovery from the anaesthetic is rapid, and the postoperative observation of levels of consciousness is not hampered by prolonged anaesthetic coma. In the case of a severely shattered jaw it may very occasionally be necessary to perform a preliminary tracheotomy and to safeguard the airway by using a cuffed rubber tracheotomy tube. Once this has been done the anaesthetic problems are much lightened.

Submandibular swellings, and other conditions which impinge on the airway

Ludwig's Angina is perhaps the best known of these conditions, being one in which there is cellulitis and oedema of all the tissue planes of the neck, but usually without frank pus. The oedema involves the mucous membrane of the pharynx and glottis, except that of the true cords which is bound tightly to the cord itself, and this is the only part of the larynx not involved in laryngeal oedema. The

has returned. At all times a pair of wire cutters must remain with the patient and there must be someone constantly with him who knows how to use them in an emergency to free the jaws. Cutting the wires is not a popular move with the surgeon and is very seldom needed, but on occasions it may be necessary.

The emergency treatment of fractured jaws and maxillo-facial injury is a most difficult anaesthetic problem, and not one to be attempted by the novice or the occasional anaesthetist. At worst one may be confronted by an unconscious patient, for head injury often accompanies maxillo-facial trauma; one who has a precarious airway which may be partly obstructed, and with bleeding in the mouth which may or may not have ceased by the time the patient is seen; one who will certainly have swallowed quantities of blood and who may also have inhaled blood and vomit. His condition may be complicated by other injuries and he will probably be suffering from oligaemic shock. Each anaesthetist will have his own method of dealing with these cases, but he may well proceed along the following general lines:

1. Attend to the airway. The patient is usually best carried and nursed semiprone before operation, and a head-down position will help remove fluids from the mouth. The gentle insertion of a Guedel airway or a nasopharyngeal tube may help, depending on the site and scope of the injury. Gentleness is essential because any movement may restart bleeding. The insertion of a soft rubber suction catheter up a nostril or the nasopharyngeal tube may clear the airway of blood and vomit.

2 Once the airway has been improved before operation, and blood transfusion and resuscitation are started, the premedication will be given (this is normally only atropine). It is best to try to raise the systolic pressure above 100 mm. Hg before starting the operation, but if bleeding is uncontrollable it may occasionally be necessary to proceed at once.

3. The needs of the induction are to provide unconsciousness and relaxation so that a cuffed endotracheal tube may be inserted at the earliest possible moment The best way of doing this depends on the circumstances, but as suitable a method as any is the use of a fractionally small dose of thiopentone, followed immediately by suxamethonium. It is again emphasised that this is not a procedure for the novice, as the anaesthetist will then have to contend with an apnoeic

procedure, which will most probably spread the infection. For the same reason local analgesia is not practicable.

Technique. The way the anaesthetic problem is tackled will depend on the individual patient and anaesthetist, but will be along the following lines:

1. A sterile tracheotomy set must be ready AND OPEN for use in case irremediable obstruction to the airway develops.

2. Premedication by atropine alone.

3. Topical analgesia of the mouth and fauces with a lozenge containing 30 milligrams of amethocaine.

4. Thorough spraying of the nares with a local analgesic and decongestant, such as 10% cocaine.

5. The introduction of a thin-walled nasal Magill endotracheal tube as far as the pharynx.

6. The passage of the malleable end of a Macintosh spray down the tube, and further spraying of the larynx with cocaine. The curve of the tube will direct the nozzle of the spray towards the cords.

7. The advancing "blind" of the tube with its "blind" passage through the cords into the trachea. It may be impossible to pass the usual size of tube through the cords, and once it has been used for the laryngeal spraying it can be withdrawn in favour of a smaller one—size 4 or 5 may be the largest which can be passed in an adult.

8. The inhalation of oxygen to relieve any cyanosis, followed by the induction using any method preferred, once the airway has been made safe. Remember that the patient will be very toxic, and intravenous drugs must be given in small doses.

The salient features are that the airway must be secured before any anaesthetic is given, and that the injection of thiopentone, whether or not with relaxants, before this has been done will result in the death of the patient.

After the operation the tube can be left in place until consciousness has returned, when it may be removed. If the airway is still inadequate, it may be replaced and left *in situ* for some hours provided the patient is sedated, by which time the operation will have relieved the tension and the swelling will have abated.

Many patients with trismus will not be in the extreme position of Ludwig's Angina. Dental causes of trismus include infected malerupted molars and infection around the lower jaw and submandibular

condition is complicated by trismus which is partly due to muscular spasm, and is partly mechanical since the swollen stiff tissues of the neck restrict jaw movements. The oedema causes respiratory obstruction, and operation with wide incision to release the tension in the neck becomes urgently necessary. These patients can be critically ill, and again the anaesthetics are not for the beginner. There are in fact probably few more difficult or fraught with danger.

The main anaesthetic problems are as follows:

1. There is obstruction to respiration, which is overcome by a concious effort to breathe, and by the use of the accessory muscles of respiration. The production of unconsciousness by any method means that these voluntary efforts to breathe are abolished, and the patient becomes anoxic. This danger is heightened if the anaesthetic used is one which is an early respiratory depressant such as thiopentone.

2. The patient is in a highly toxic state in these infections, and there is usually a dangerous degree of myocarditis. Any additional toxaemia or hypoxia may cause cardiac arrest.

3. There is the possibility that the toxaemia and inflammation in the neck sensitises the carotid body and the chemo- and pressure receptors in the area, so that there is undue liability to cardiac arrest from vagal inhibition if operation is undertaken without adequate anaesthesia Some writers deny this factor is operative, but the possibility must be borne in mind.

4. The precarious patency of the airway may be maintained only with the help of the muscular tone of the pharynx. Once anaesthesia is induced, manual inflation of the lungs may be impossible.

5. The trismus and swelling prevent the mouth being opened and the larynx visualised for intubation. Relaxants will not alter the *mechanical element of the trismus nor the swelling of the larynx,* though they will of course abolish the muscular spasm. For these reasons and No 4 above the administration of intravenous anaesthetics followed by a relaxant, in the hope that an airway can at once be provided by intubation, leads only to disaster.

6. The cellulitis of the neck makes elective preoperative tracheotomy to relieve the respiratory obstruction a hazardous (and difficult)

thetic mask to ensure (a) that the nitrogen in the lungs is replaced by oxygen, (b) that the plasma is in equilibrium with a high partial pressure of the gas, and (c) that the haemoglobin is 100% oxygenated, a condition which may not have existed beforehand if the cardiac disease is accompanied by any pulmonary pathology, or the premedication has caused respiratory depression. All these factors provide a reserve, in case the induction is complicated by events which might otherwise cause hypoxia—such as laryngeal spasm or difficulty in intubation.

The pre-oxygenation can be followed by whatever induction is desired, but it must go smoothly without a hitch. Thiopentone is very suitable in expert hands, but it is essential that the very prolonged circulation time found in these diseases is remembered, and that the patient is not thought to be requiring a large dose of the drug when all that has happened is that the injected dose has not yet reached the heart and brain. The arm-to-brain circulation time may be prolonged to 1 minute or more in these cases, which means that this length of time elapses before the effect of the injection starts.

The use of 2½% solution will help to reduce the risk of overdosage and it is important to wait as long as necessary for the effect of a very small dose such as 2 ml. of 2½% solution (50 milligrams) to be seen before it is decided whether more will be required It should be followed by a short acting relaxant such as suxamethonium, then by a rapid and skilful intubation, and by respiring the patient with a mixture containing at least 40% oxygen until he is breathing well on his own. He should continue to breathe at least this concentration of oxygen throughout operation

Some anaesthetists prefer to avoid intravenous barbiturates in these cases, and induce sleep with cyclopropane, giving a relaxant as soon as unconsciousness is reached. This has the advantage that the uptake of the anaesthetic is limited by the efficiency of the circulatory and respiratory systems, and overdose cannot be given inadvertently, while the presence of about 80% oxygen is helpful. The excitement stage may be troublesome with this technique.

Other ill patients are treated along the same lines, the precise drugs used being less important than the skill of the anaesthetist. His aim should always be to give a smooth anaesthetic, avoiding any untoward incidents, particularly hypoxic ones, which might

region. The criterion of hazard is the presence or otherwise of respiratory obstruction. An inhalational induction such as cyclopropane and oxygen is advised, which should be preceded by inhalation of oxygen for 3 minutes for the reasons elaborated below. Once the patient is unconscious it may be possible to open the mouth sufficiently to see the cords, but the relaxant may not be given until it is certain that there will be no barrier to inflating the patient with oxygen. The old-fashioned manœuvre of blind intubation is of great help in all such cases as well as those described earlier, and will enable tubes to be passed when direct laryngoscopy is impossible.

For a patient who has a localised submandibular swelling of dental origin which it is proposed to incise from outside the mouth and which is not causing respiratory obstruction, anaesthesia may be given using a non-irritant inhalational agent such as cyclopropane via a facepiece for induction, followed by the passage of a short nasopharyngeal airway and continuing administration through this without tracheal intubation.

To recapitulate. If there is any degree of respiratory obstruction the patient must be intubated before anaesthesia is begun. Thiopentone is lethal

The unfit patient who is admitted to hospital because he is not suitable for "gas" in the dental chair.

It has been described in Chapter 8 how the main cause of unfitness for nitrous oxide as an outpatient is pre-existing pathology which makes the patient unduly susceptible to the effects of hypoxia, such as myocardial ischaemia. A patient who has had coronary thrombosis within the last six months should not be submitted to general anaesthesia for any condition except an emergency which cannot for technical reasons be dealt with under local analgesia, since the anaesthetic in such cases presents a small but definite risk to life. If general anaesthesia is imperative it must be conducted in such a way, and using such agents, as to avoid any degree of hypoxia, in fact to give an oxygen rich mixture and to avoid any gross alteration in blood pressure in either direction.

Premedication should be liberal to bring the metabolic demands as far to the basal level as possible. Induction should be preceded by a 3-minute period of breathing 100% oxygen through the anaes-

thetic mask to ensure (a) that the nitrogen in the lungs is replaced by oxygen, (b) that the plasma is in equilibrium with a high partial pressure of the gas, and (c) that the haemoglobin is 100% oxygenated, a condition which may not have existed beforehand if the cardiac disease is accompanied by any pulmonary pathology, or the premedication has caused respiratory depression. All these factors provide a reserve, in case the induction is complicated by events which might otherwise cause hypoxia—such as laryngeal spasm or difficulty in intubation.

The pre-oxygenation can be followed by whatever induction is desired, but it must go smoothly without a hitch. Thiopentone is very suitable in expert hands, but it is essential that the very prolonged circulation time found in these diseases is remembered, and that the patient is not thought to be requiring a large dose of the drug when all that has happened is that the injected dose has not yet reached the heart and brain. The arm-to-brain circulation time may be prolonged to 1 minute or more in these cases, which means that this length of time elapses before the effect of the injection starts.

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pass unnoticed in the fit but which can tip the scales against the frail.

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CHAPTER ELEVEN

Other Techniques

Analgesia

THE inhalation of sub-anaesthetic concentrations of nitrous oxide causes reduction in appreciation of pain without much impairment of consciousness or of the other senses. This is the state of analgesia and it is possible to make use of this in the preparation of cavities, and other painful procedures in the dental chair which do not justify the giving of a full general anaesthetic. Analgesia is not suitable for dealing with acutely painful procedures such as the extraction of teeth or the incision of septic areas, and many procedures where it might be of use are more expeditiously and appropriately performed under a local anaesthetic.

Technique. In all analgesic procedures it must be explained very carefully beforehand to the patient that although he will not feel pain he will be aware of all that is going on, and that in particular he will appreciate touch. The analgesic state is pleasant and the subjective feelings are of remoteness and warmth.

Analgesia may be either self-administered by the patient, or given by an anaesthetist. The former is rarely so successful but it is accomplished by settling the patient in the chair, inserting a dental prop and loosely packing the mouth, and adjusting the anaesthetic harness and mask so that if the patient inspires through his nose he will inhale gases from the machine, and if through the mouth he will breathe air. The machine is turned on and set at low pressure to deliver a mixture of 50:50 nitrous oxide and air, or between 60:40 and 80:20 nitrous oxide and oxygen, and the patient is instructed to inspire through his nose if he feels pain. The 50:50 gas and air mixture is insufficient to produce unconsciousness in most people, but will do so in those susceptible. Stronger gas mixtures will give stronger analgesia, but prolonged breathing of them will bring unconsciousness. If that does happen, nasal breathing will usually

pass unnoticed in the fit but which can tip the scales against the frail.

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ANDERSON, S. (1951). *Lancet* **2**, 965, "Use of Depressant and Relaxant Drugs in Infants and Children".

SHACKLETON, R. P. W. (1944). *Lancet* **1**, 396, "Anaesthesia in Fractures of the Jaws".

for which they are designed demand that the vapour strength they give is on the low side, for safety. Other inhalers, not temperature compensated, are on the market, and Freedman's is one which is suitable for dental purposes. The nasal mask is placed on the patient as before, but the proximal end of the tubing is connected to the vaporiser instead of the gas machine. The procedure is identical to "gas and air" but while the analgesia produced is more profound, recovery is slower and nausea more common.

Other devices have been produced in which the patient vaporises the trilene by the action of a rubber bulb held in the hand, which he can pump when he feels pain. If unconsciousness approaches he will cease to pump the bulb and will no longer receive anaesthetic. A similar device has been marketed for turning on the gas machine by a hand-operated bellows.

The analgesic state has its own rather wide limitations, but it has its uses for the occasional patient who cannot for any reason tolerate local anaesthesia. Just as strict precautions must be taken as under full anaesthesia to have a chaperone present when treating women patients —perhaps even more so since the prolonged maintenance of the first stage is ideal for the imaginative to dream up fancied assault. It is still important for the stomach to be empty before the procedure starts.

Gas and Air

Before the design of satisfactory intermittent-flow apparatus some decades ago it was the widespread custom to use the atmosphere as the source of oxygen during dental nitrous oxide anaesthesia. The simplest apparatus is required—a cylinder of nitrous oxide, usually with a foot key and without a regulator, which is connected by narrow tubing to a large reservoir bag of at least 2 gallons capacity, which in turn is attached by tubing to a standard nasal mask. In use the gas is turned on to fill the bag comfortably and the mask applied as in Chapter 4. When anaesthesia arrives, instead of adding oxygen to the gases the mask is lifted from the face and the patient allowed one breath of air, following which the mask is re-applied for a further four breaths of nitrous oxide followed by one breath of air, and so on. Depth of anaesthesia is regulated by altering the relative numbers of breaths of air and nitrous oxide.

Disadvantages. The inhaled gases comprise about $\frac{4}{5}$ nitrous oxide,

give place to oral, and the patient will cease to inhale the gas and will awaken. The operator must keep a careful look-out for the patient who continues nasal breathing while asleep, or who finds the sensation so pleasant that he continues to inhale in the absence of pain. The success of the manœuvre depends much upon the selection of patients, for it demands a degree of co-operation which many cannot provide, and the supervision of the job distracts the operator from his work. It is very easy to pass from stage one of analgesia to sudden violent and drunken-type behaviour of stage two.

Better results can be obtained if an anaesthetist is present throughout He will then instruct the patient, administer the analgesia, and relieve the operator from responsibility for the patient's welfare. The analgesic state should be induced before the painful stimulus arrives, and by co-operation and anticipation he can give analgesia as and when it is required, letting the patient come round completely between painful stages. He can enhance the analgesic content of the mixture as he pleases, but will do well to avoid mixtures stronger than 80:20 nitrous oxide–oxygen since this will produce hypoxia and eventually nausea, and he will also find it advisable not to take the patient into unconsciousness. The trouble will not lie in inducing anaesthesia but in avoiding some degree of excitement on recovery. Almost the same care in selecting cases is necessary as when no anaesthetist is present. The analgesia may be prolonged as long as necessary providing no hypoxia is permitted to develop, but after about half an hour's operating time with intermittent analgesia, it becomes progressively more difficult to maintain the desired state, and a session which is unwisely prolonged is sometimes abruptly terminated by the patient vomiting.

Another agent which is popular in the U.S.A. but less so in this country for dental work is trichloroethylene (Trilene). This is, however, widely used here for analgesia in labour, and a number of British inhalers have been designed for the purpose, using air drawn by the patient as a vehicle for the vapour of the drug. In particular two types of inhaler, the Emotril and the Tecota, are sufficiently foolproof and compensated for changes in temperature to give concentrations of trilene vapour which can be relied upon to remain constant under all conditions of use. They have consequently been officially approved for use by the patient in midwifery in the absence of a doctor. They are very suitable for dental work but the conditions

Some limb movements are seen when extractions are made in this state, but contrary to expectation the patients remember nothing and though not truly unconscious are in a state of unawareness. Most of Tom's cases have been children in school dental clinics, but he finds the technique satisfactory in adults too. The method has interesting possibilities, particularly for patients in whom the slightest degree of hypoxia is contraindicated.

Pre-Oxygenation

More recently Mostert has drawn attention again to the advantages which can accrue from giving the patient pure oxygen to breathe before starting induction with nitrous oxide. The principles involved are that the inhalation of pure oxygen for two minutes will wash out of the lungs over 95% of the nitrogen that they normally contain, and will leave the alveoli filled only with oxygen, carbon dioxide and water vapour. This will result in a small increase in oxygen carried by the blood (about 2 volumes per cent)—0·5 ml. the result of increasing the haemoglobin saturation from 97% to 100%, and 1·5 volumes more dissolved in the plasma. These figures apply to the healthy lung, but not necessarily to one in which the distribution and mixing of inhaled gases has been made abnormal by pulmonary disease, and of course nitrogen is not removed from the *blood* in appreciable quantities, a process which requires many hours to be completed. When the nitrogen has been removed from the lungs and the whole blood volume has had the opportunity to pass through the lungs, processes which should both be practically complete in about 2 minutes in the healthy adult, pure nitrous oxide is given. This will reduce the alveolar oxygen to low levels, but much more slowly in this technique where the fall starts from 95% than when N_2O is given undiluted from the start and the fall starts from 14%. After about 1 minute the patient will be anaesthetised, but there will have been no hypoxia. The operation now starts and the inhaled oxygen is simultaneously increased to 10–15%. After 30 seconds of this concentration it is again increased to 20%, where it remains for the duration of the anaesthetic.

During this phase the anaesthetic will lighten, and if the operation is to be further prolonged, a supplementary drug must be given in most cases, for example trichloroethylene or halothane.

$\frac{4}{5}$ air, i.e. 80% nitrous oxide, 16% N_2, 4% O_2. Not only is 4% of oxygen inadequate to maintain life over any but the shortest periods but the concentration of nitrous oxide is reduced from about 93% in the gas and oxygen method to 80% in this technique, losing much of its potency. In effect true anaesthesia of nitrous oxide is being lost and being compensated by even greater hypoxia than in the standard method. Although adequate results can be obtained for the few seconds required to extract one tooth it is not possible to maintain anaesthesia for anything approaching the time available with oxygen instead of air in the mixture. Ill-advised attempts to do so run the risk of profound anoxia, and it was because of this that the present-day machines and technique were developed. It is claimed for this method that it is easier to administer than nitrous oxide and oxygen in the sense that a given error in admitting air results in only $\frac{1}{5}$ that error in the oxygen. The patients are thus less likely to become suddenly unmanageably light, but the use of an anoxic technique cannot be justified nowadays The method is mentioned because the practitioner may be presented with a "machine" consisting of only this primitive apparatus and may then have to do the best he can with it.

Amnalgesia

Recent work has re-aroused interest in methods for giving nitrous oxide in the presence of sufficient oxygen to avoid hypoxia. Tom has published a technique which he and others describe as "amnalgesia", the purpose of which is briefly to make use of the analgesic and amnesic state provided by keeping the patient between the first and second stages of anaesthesia, but not surgically anaesthetised in the accepted sense.

Method. Not more than six breaths of pure nitrous oxide are given at the start to hasten an otherwise rather slow induction. After this the patients are at once given 80% nitrous oxide and 20% oxygen (85% and 15% in young children who are expected to dilute the mixture still further by mouthbreathing). After 40–50 seconds the "amnalgesic" state is reached, heralded by a slight hesitation in breathing The patients are still able to comply with instructions and will again breathe steadily if told to do so. The breathing is not of the "automatic" type associated with the advent of surgical anaesthesia, and the patient is still pink. The eyelids are soft and the eyes deviated.

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The advantages of this technique are that complete anaesthesia, as opposed to amnalgesia, is produced by N_2O and O_2 alone without hypoxia for time enough for short procedures to be completed. The patients feel well afterwards, and some prefer induction by this method, which gives different subjective sensations to those accompanying the hypoxia of conventional inductions. The method is suitable for the unfit patient.

The disadvantages are the prolonged pre-anaesthetic oxygenation of the conscious patient, because some dislike having the mask applied to their face for two minutes before they are unconscious; the exact and precise timing which must be adhered to for success; and the increased need to supplement with other drugs.

For exact details the original paper should be consulted

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GRAY'S ANATOMY

Some press opinions continued

graphs, and its excellent radiographs, which *could not be bettered.*

"Although Gray's Anatomy has always been descriptive and applied, yet never before has the work given more to the surgeon than it does today.

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